June 1993

USE OF ARTIFICIAL PROPAGATION AND SUPPLEMENTATION FOR REBUILDING SALMON STOCKS LISTED UNDER THE ENDANGERED SPECIES ACT

Recovery Issues for Threatened and Endangered Snake River Salmon
Technical Report 5 of 11

Technical Report 1993

DOE/BP-99654-5

DOE/BP-99654-5

This report was funded by the Bonneville Power Administration (BPA), U.S. Department of Energy, as part of BPA's program to protect, mitigate, and enhance fish and wildlife affected by the development and operation of hydroelectric facilities on the Columbia River and its tributaries. The views of this report are the author's and do r necessarily represent the views of BPA.

This document should be cited as follows:

Lichatowich,Jim; Bruce Watson, S.P. Cramer & Associates, Inc., U.S. Department of Energy, Bonneville Power Administration, Division of Fish and Wildlife, Project No. 93-013, Contract No. DE-AM79-93BP99654, 117 electronic pages (BPA Report DOE/BP-99654-5)

This report and other BPA Fish and Wildlife Publications are available on the Internet at:

http://www.efw.bpa.gov/cgi-bin/efw/FW/publications.cgi

For other information on electronic documents or other printed media, contact or write to:

Bonneville Power Administration
Environment, Fish and Wildlife Division
P.O. Box 3621
905 N.E. 11th Avenue
Portland, OR 97208-3621

This report was funded by the Bonneville Power Administration (BPA), U.S. Department of Energy, as part of BPA's program to protect, mitigate, and enhance fish and wildlife affected by the development and operation of hydroelectric facilities on the Columbia River and its tributaries. The views in this report are the author's and do not necessarily represent the views of BPA.

For additional copies of this report, write to:

Bonneville Power Administration
Public Information Office - ALP-22
P.O. Box 3621
Portland, OR 97208

Please include title, author, and DOE/BP number from back cover in the request.

USE OF ARTIFICIAL PROPAGATION AND SUPPLEMENTATION FOR REBUILDING SALMON STOCKS LISTED UNDER THE ENDANGERED SPECIES ACT

Recovery Issues for Threatened and Endangered Snake River Salmon
Technical Report 5 of 11

Prepared by

Jim Lichatowich[1]
Bruce Watson[1]

under subcontract to

S.P. Cramer & Associates, Inc.
Gresham, OR

Prepared for

U.S. Department of Energy
Bonneville Power Administration
Division of Fish and Wildlife
P.O. Box 3621
Portland, OR 97208-3621

Project No. 93-013
Contract No. DE-AM79-93BP99654

June 1993

---

[1] Mobrand Biometrics, Inc., Vashon Island, WA

ACKNOWLEDGEMENTS

This report is largely based on the discussions and work products of the team of biologists that participated in the Regional Assessment of Supplementation Project. The team included Tom Backman, Ed Bowles, Craig Busack, Rich Carmichael, Duane Fickeisen, Larry Lestelle, Jim Lichatowich, Rich Lincoln, Lars Mobrand, Willa Nehlsen, Rich Turner, Tom Vogel, Harry Wagner, and Bruce Watson.

Deborah Watkins served as Project Manager for Bonneville Power Administration.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

EXECUTIVE SUMMARY

Conventional hatcheries, supplementation, and habitat protection are management activities located on a production continuum (see figure 1 in the report). At one end of the continuum is the conventional hatchery which attempts to separate artificially propagated fish from naturally reproducing populations. On the other end of the continuum is natural production. Supplementation which attempts to increase natural production through the use of artificial propagation lies somewhere between natural production and conventional hatcheries on the continuum.

The use of artificial propagation in the recovery of listed species is controversial (Frazer 1992, Snyder and Snyder 1988, and Meffe 1992). Guidance on the use of artificial propagation in the recovery of listed species comes from three sources: The Endangered Species Act (ESA), U.S. Fish and Wildlife Service (USFWS) policies and 'National Marine Fisheries Service (NMFS) guidelines. The ESA states that its purpose is:

> ***To provide a means whereby the ecosystems upon which endangered species and threatened species depend may be conserved, to provide a program for the conservation of such endangered species and threatened species, and to take such steps as may be appropriate to achieve [these] purposes...***

The key word in that statement is ecosystems. It implies that the listed species must be maintained through the functioning of a natural production system. It does not suggest that either an. integrated natural and artificial or a strictly artificial production system is an appropriate substitute for all or part of the natural ecosystem. This interpretation is reflected in the U.S. Fish and Wildlife Service's policy on recovery (USFWS 1990) which states:

> ***Captive propagation/cultivation may be a useful tool to facilitate recovery of a species in the wild, but it is not a substitute for reestablishment of viable wild populations. The initiation of significant and costly captive propagation or cultivation programs may be necessary, but should be 'considered only after all techniques to maintain or improve a species status in the wild have failed or are determined as likely to fail. In the case of listed plants, however, seed banking may be relatively simple and inexpensive and need not be delayed.***
>
> ***Emphasis should be on preservation of natural habitats, population management, enforcement of protective regulations, and public education.***

In addition to the general guidelines contained in the USFWS (1990), NMFS (Hard et al. 1992) contains guidelines that deal specifically with the propagation of listed Pacific salmon. Because they are so widely and extensively propagated in hatcheries, the use of artificial propagation in the recovery of listed Pacific salmon species raises some unique questions. For example, when are hatchery fish considered part of the evolutionarily significant unit (ESU) (see Section 1.3 for

a definition of ESU) and when and to what extent does the propagation of unlisted populations create a conflict with the recovery of the listed ESU's?

Hard et. al **(1992)** suggests that artificial propagation may be consistent with the purposes of the ESA when:

> ***1) A rtificial propagation facilitates recovery of a listed species, or***
> ***2) When enhancement of unlisted populations does not impede the recovery of listed species or compromise the viability or distinctiveness (and hence be a factor in the listing) of an unlisted species.***

The NMFS guidelines also state:

> ***The most compelling reason for the use of artificial propagation in ESA recovery plans is when extinction of the natural population is likely before natural recovery can occur***
>
> ***There are also two special cases in which artificial propagation may warrant high priority among recovery options. First, the outplanting of artificially propagated fish may be necessary to aid recolonization of unutilized but suitable habitat if natural straying is not likely to reseed the habitat within an acceptable time. (This is on example of 'transplantation" recognized in the definition of conservation given in the Section 3(3) of the ESA.) Second, artificial propagation may be necessary in recovery when habitat crucial to the natural population is lost. In this case, artificial propagation provides temporary means of conserving a natural population until new or reclaimed habitat becomes available.***

The use of artificial propagation in the recovery of listed species of Pacific salmon should be considered as a last resort and it has to be considered a temporary measure because recovery of the species in its natural habitat is a prerequisite to delisting. If the species requires human intervention in the form of artificial propagation and rearing to survive it cannot be considered "recovered." Although it is possible to use propagation techniques for recovery that are located along the whole production continuum, the prudent manager should attempt to minimize human intervention and remain as far possible to the right side of Figure **1.**

Given the above background, this report has three goals: 1) To provide guidelines for the use of artificial propagation in recovery plans, 2) to provide a general review of biological constraints on artificial propagation, and 3) to review policies of state and federal agencies regarding the use of artificial propagation (the policies are presented in Appendix B).

Clear communication among scientists and managers is impossible without precise, universally accepted definitions. Among agencies implementing artificial propagation, many key terms are undefined or vaguely defined, and agreement between agencies is rare. Semantic ambiguity is particularly prevalent where genetic issues are concerned, **which is** especially unfortunate in the context of ESA recovery plans because the fundamental intent of the Act is preservation of adaptive gene pools. We have identified the conventional definitions for those terms commonly used in artificial propagation.

Recovery of a listed stock entails the retention of the genotypes that embody the evolutionary legacy of the stock. Similar considerations apply to borderline listable stocks. Thus a supplemented population must retain ***a large m easure*** of its genetic variability and distinctiveness. This is so not only because of a loss of within- or between-stock variability, or artificial selection, can be' expected to decrease fitness and increase the already high probability of extinction; but because the unique adaptive gene pool the ESA was written to preserve will have otherwise been destroyed directly, before the physical elimination of the population.

In the sense that it is used here, "experiential" constraints refer to non-genetic factors such as physiological conditions of the hatchery reared fish that affect their ability to bolster natural production and promote numerical viability of the targeted stock. Experiential effects are expressed through "post-release survival," and "reproductive success." Post-release survival, the proportion of hatchery reared smolts that survive to adulthood, can be analyzed as the product of a series of life-state-specific survival rates (survival through the subbasin, through the mainstem Snake/Columbia, through estuarine rearing, and through maturation in the ocean). Reproductive success, here defined as the number of smolts produced per spawner, is also the product of a series of rates: mean eggs per female, pre-spawning survival, proportion of adult recruitment homing to correct drainage and to quality spawning areas within the drainage, proportion of effective spawners (re. mate acquisition, redd digging ability, spawning timing and egg retention), and survival or progeny across significant life stages (egg-to-fry, fry-to-presmolt and presmolt-to-smolt). All of these rates for a supplemented population are subject to genetic, ecological and "experimental" modification. ***Experiential*** impacts consist of a list of cultural practices that can alter behavior, physiology and morphology of supplementation fish ***directly***, without genetic mediation.

Ecological constraints also affect the ability of the population to attain numerical viability, but the mechanism is mediated by abiotic and biotic environmental factors, not cultural practices. The discussion on ecological constraints highlights habitat conditions and inter- and intra-specific interactions that could prevent increases in post-release survival or reproductive success for a depressed supplemented population.

The planning guidelines presented in this report are not rules to be followed in every detail. Their purpose is to guide the development of supplementation plans through a focus on the life history-habitat relationships of the population to be restored. All the detailed information called for in the guidelines does not need to be in hand before the recovery plan is implemented. In some cases, information on life histories and habitat will be sparse, in other cases it will be extensive. Where recovery using artificial propagation is implemented without all the requisite information, these planning guidelines become iterative. Once the plan is implemented, monitoring and evaluation will begin to generate the missing information which leads to an iterative update of the plan.

The ESA specifies that its goal is the conservation ·**of** ecosystems upon which the endangered species depend. That goal requires that the recovery plan focus on the restoration of ecological relationships as well as the numerical size of the ESU. While restoration of fish numbers is important, a sustainable increase in population size requires the restoration of important ecological relationships. Successful ecological restoration is the acid test of our understanding of how the elements of an ecosystem function (Bradshaw 1990). Restoration, measured as an increase in natural production **and** accomplished through the use of supplementation, is a test of our understanding of the relationships **among** the life history of the target stock, its habitat, and artificial propagation This understanding is developed and demonstrated through the completion of steps 2-6 in the planning process.

When using supplementation to recover an ESU, it is important to avoid the traditional approach of focusing exclusively on production -- hatchery sizing, feed programming, release targets, and escapement goals. The guidelines described here ask the recovery team contemplating the use of supplementation to first look back in time at the stream/stock system before degradation occurred and then to describe how the original system functioned. This is an essential step because it focuses attention on ecological relationships early in the planning process.

The planning guidelines are comprised of 9 steps (Figure 2) which are described within the context of a clinical model. In the first step goals are established, steps 2 to 4 are fact-finding and descriptive; steps 6 and 7 involve analysis of risks **and** benefits, and steps 8 and 9 are monitoring and evaluation. We use clinical terminology to describe the 9 planning steps. For example, the degraded ecosystem and population is the patient and a correct diagnosis is critical to the selection of an appropriate treatment. The 9 steps are:

1. **Identify** Recovery **Objectives.** The objective describes the desired future condition of the stream/stock system (expected benefits).

2. **Describe Template. The** template describes the healthy stream/stock system.

3. **Describe Patient** The patient describes the current condition of the stream/stock system.

4. **Make Diagnosis.** The diagnosis identifies limiting factors that prevent the patient from reaching the objective.

5. **Revise Objective.** At this point the original objective should be reviewed and revised if appropriate.

6. **Recommend Treatment** The treatment describes the artificial propagation strategies expected to achieve the objective.

7. **Risk Analysis.** Risk analysis is based on the uncertainties associated with the recommended treatments.

8. **Design and Implement Monitoring and** Evaluation. Risk is “managed” through monitoring and research.

9. **Evaluate** Results. M & E results are evaluated following implementation and the plan is revised consistent with the new information.

USE OF ARTIFICIAL PROPAGATION
AND SUPPLEMENTATION FOR REBUILDING

1. INTRODUCTION

1.1 GENERAL POLICIES AND GUIDELINES

Conventional hatcheries, supplementation and habitat protection and restoration are management activities located on a production continuum (Figure 1). At one end of the continuum is natural production, and at the other end, conventional hatcheries. Managers further natural production through actions designed to protect and restore habitat productivity and ensure adequate escapement of spawners. Conventional hatcheries, which are operated to supply fish to sport and commercial fisheries, attempt to isolate to the extent possible, the artificially propagated salmon from other fish in the ecosystem. Supplementation lies near the center of the continuum. Its objective is to integrate the natural and artificial production systems and ultimately increase natural production. Figure 1 highlights three points on the production continuum but there are a variety of management activities between natural production and conventional hatcheries. This report does not attempt to describe all the variations in the use of hatchery technology. It does provide guidelines' for incorporating a variety of artificial propagation strategies into recovery plans.

The use of artificial propagation in the recovery of listed species is controversial (Frazer 1992, Snyder and Snyder 1988, and Meffe 1992). The decision to employ artificial propagation and the specific type of artificial propagation used are contingent on both the status of the species and its ecosystem. Guidance on the use artificial propagation in the recovery of listed species comes from three sources: The Endangered Species Act (ESA), U.S. Fish and Wildlife Service (USFWS) policies and National Marine Fisheries Service (NMFS) guidelines. The ESA states that its purpose is:

> ***To provide a means whereby the ecosystems upon which endangered species and threatened species depend may be conserved, to provide a program for the conservation of such endangered species and threatened species, and to take such steps as may be appropriate to achieve [these] purposes...***

The key word in that statement is ecosystems. **It** implies that the listed species must be maintained. through the functioning of a natural production system. It does not suggest that either

[1] The guidelines presented here have been adapted from the Regional Assessment of Supplementation Project (RASP) (1993).

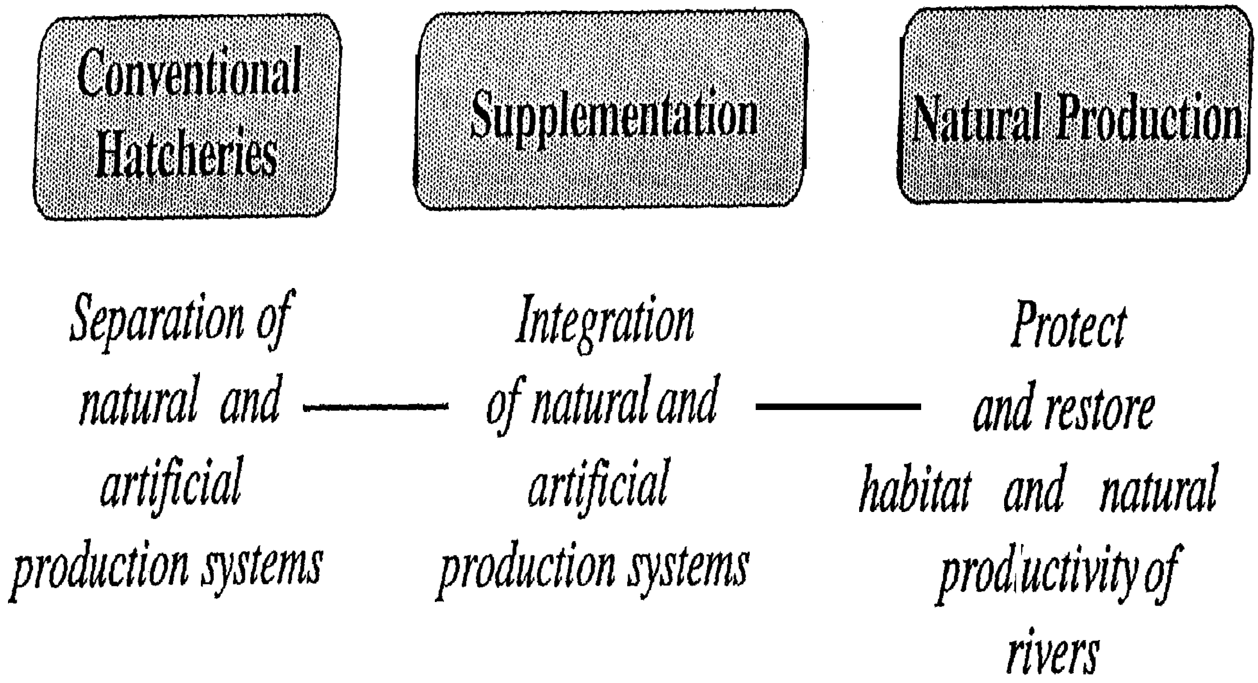

Figure 1, Production Continuum.

an integrated natural and artificial or a strictly artificial production system is an appropriate substitute for all or part of the natural ecosystem. This interpretation is reflected in the U. S. Fish and Wildlife Service's policy on recovery (USFWS 1990) which states:

> *Captive propagation/cultivation may be a useful tool to facilitate recovery of a species in the wild, but it is not a substitute for reestablishment of viable wild populations. The initiation of significant and costly captive propagation or cultivation programs may be necessary, but should be considered only after all techniques to maintain or improve a species status in the wild have failed or are determined as likely to fail. In the care of listed plants, however, seed banking may be relatively simple and inexpensive and need not be delayed.*
>
> *Emphasis should be on preservation of natural habitats, population management, enforcement of protective regulations, and public education.*

In addition to the general guidelines contained in the USFWS (1990), NMFS (Hard et al. 1992) contains guidelines that deal specifically with the propagation of listed Pacific salmon. Because they are so widely and extensively propagated in hatcheries, the use of artificial propagation in the recovery of listed Pacific salmon species raises some unique questions. For example, when are hatchery fish considered part of the evolutionarily significant unit (ESU) (see Section 1.3 for a definition of ESU) and when and to what extent does the propagation of unlisted populations create a conflict with the recovery of the listed ESU's?

Hard et al. (1992) suggest that artificial propagation may be consistent with the purposes of the ESA when:

I A rtificial propagation facilitates recovery of a listed species, or
2) When enhancement of unlistedpopulations does not impede the recovery of listed species or compromise the viability or distinctiveness (and hence be a factor in the listing;) of an unlisted species.

The NMFS guidelines also state:

> *The most compelling mason for the use of artificial propagation in ESA recovery plans is when extinction of the natural population is likely before natural recovery con occur.*
>
> *There are also two special cases in which artificial propagation may warrant high priority among recovery options. First, the outplanting of artificially propagated fish may be necessary to aid recolonization of unutilized but suitable habitat if natural stmying is not likely to reseed the habitat within on acceptable time. (This is an example of "transplantation" recognized in the definition of conservation given in the Section 3(3) of the ESA.) Second, artificial propagation may be necessary in recovery when habitat crucial to the natural population is lost. In this case, artificial propagation*

provides temporary means of conserving a natural population until new or reclaimed habitat becomes available.

The use of artificial propagation in the recovery of listed species of Pacific salmon should be considered as a last resort and it has to be considered a temporary measure because recovery of the species in its natural habitat is a prerequisite to delisting. If the species requires human intervention in the form of artificial propagation and rearing to survive it cannot be considered "recovered." Although it is possible to use propagation techniques for recovery that are located along the whole production continuum (Figure 1), the prudent manager should attempt to minimize human intervention and remain as far as possible to the right side of Figure 1.

1.2 SCOPE AND DIRECTION OF THIS REPORT

To provide background for the planning guidelines, we summarize the biological constraints that must be considered in the design of propagation projects in Section 2. In addition to the federal ESA guidelines, state, federal and tribal fisheries agencies have promulgated policies governing the use of artificial propagation and the interaction between propagated and wild fish. While these policies are not officially part of the ESA or its implementing policies, they do offer useful background information for the design of artificial propagation projects. Those policies and guidelines are summarized in Section 3.

For the purpose of this report we define conventional hatchery programs as the attempt to circumvent the spawning, incubation and rearing phases of the freshwater life history through hatchery technology for the purpose of increasing total contribution to the fisheries. Interaction between propagated and wild fish should be minimized by maintaining temporal and spacial separation to the extent possible. However, in practice, most current hatchery programs that might be considered conventional do not maintain separation between hatchery and wild populations. We believe conventional hatchery practices present enough genetic and ecological risks to listed species as to limit their consideration in recovery programs to unusual circumstances. For example, a listed species faced with eminent extinction might be propagated in a hatchery throughout its entire freshwater and marine life history (captive brood) to avoid factors causing depletion and rapidly build the broodstock.

Supplementation, as defined by the Regional Assessment of Supplementation Project (RASP) (1993), is:

The use of artificial propagation in an attempt to maintain or increase natural production while maintaining the long-tenn fitness of the target population, and keeping the ecological and genetic impacts on nontarget populations within specified biological limits.

The objective of increasing natural production* and the constraints of maintaining long-term fitness and keeping ecological and genetic impacts on nontarget species within specified limits are consistent with the guidelines and policies of both the USFWS and NMFS. Although the intent and constraints on supplementation are consistent with recovery guidelines and policies, this technology is still unproven so each specific application of it must be considered experimental with appropriate monitoring and evaluation.

The purpose of Section **4** is to describe a set of guidelines to be followed when incorporating artificial propagation into a recovery plan for listed ESU's of Pacific salmon. However, a critical step that precedes the design of artificial propagation for recovery plans is the decision that propagation is an appropriate action. Unlike management programs where supplementation or conventional hatcheries might be employed as a permanent solution to the need for greater production, in recovery plans, the use of artificial propagation is a temporary, last resort activity. If the ESU is to be delisted, it cannot become dependent on artificial propagation for survival. The difference between recovery and conventional management plans, requires that we include guidelines to determine when propagation is an appropriate part of the recovery plan. Those, guidelines are given in Section **4.**

13 DEFINITIONS

Clear communication among scientists and managers is impossible without precise, universally accepted definitions. Among agencies implementing artificial propagation, many key terms are undefined or vaguely defined, and agreement between agencies is rare. Semantic ambiguity is particularly prevalent where genetic issues are concerned which is especially unfortunate in the context of ESA recovery plans because the fundamental intent of the Act is preservation of adaptive gene pools.

Table 1 summarizes the definitions of terms and phrases comprising the essential vocabulary of artificial propagation and ESA recovery programs. Unless otherwise indicated, all definitions were taken from documents supplied to the Integrated Hatchery Operations Team (IHOT) or discussed by Kapuscinski (1991). The table lists terms and phrases in the left column, agency attribution in the center and alternative definitions on the right. Note that a suggested standard definition is included for a number of terms. This report employs suggested standard usage when one has been identified. The table includes alternate definitions used by the following agencies: Idaho Fish and Game (IDFG), Oregon Department of Fish and Wildlife (ODFW), Washington Department of Fisheries (WDF), Washington Department of Wildlife (WDW), U.S. Fish and Wildlife Service (USFWS), National Marine Fisheries Service (NMFS) and the Columbia River Intertribal Fish Commission (CRITFC). The absence of an agency-specific definition indicates no definition was found in the materials reviewed.

*Natural production is defined as production resulting from naturally produced progeny that have spent their entire life in their natural habitat (RASP 1993).

Table 1, **Definitions** of key **terms** relative to **artificial** propagation aud natural **populations in the** context of **the Endangered Species** Act.

TERM OR **PHRASE**	**AGENCY** ATTRIBUTION OR SUGGESTED **STANDARD** USAGE	DEFINITION
allele	Suggested standard **(Kapuscinski,** 1991)	An **alternative form** of **the** some **gene.**
	WDF	One of two or more **alternate** forms of a **gene.**
artificial propagation	ODFW	**[Artificial]** propagation of **fish** means **the spawning, incubating, and/or rearing** of **fish** by **a human for sale,** release or **other** uses. ***[Standard definition needed.]***
depressed	ODFW	Below **and** established **goal such** as **a fish** production or **escapement goal shown in a** management **plan,** or **below the level** of production or escapement **that the Commission determined** to be **an optimal** level, ***[Given*** 1 ***frequency and*** vagueness ***with which this term is used,*** a ***standard definition is needed.]***
effective population she	**Suggested standard (Kapuscinski,** 1991)	The number of **reproducing** individuals **in** an ideal **population that would lose genetic** variation due to genetic drift **and inbreeding** at **the** same rate as **the number** of **reproducing** adults in **the real population under** consideration,
	NMFS (Hard et, al,, **1992)**	Effective population **size,** N,, is a mathematical **construct that** takes **into account** skewed **sex ratio and** variance in **progeny** number, **as** well as **the actual** number of **breeders,** to **estimate the** number al **effectively breeding** individuals **in a population.** N_e **is the size** of **an idealized** population **(i.e., one in which sexes** are **equally represented, parents** are randomly mated, and **numbers** of **progeny** are randomly distributed among **families) that shows the** same rate of **loss** of **genetic** variability **as** the observed population **(Falconer,** 1981; Laude **and Barrowclough, 1987).**
enhancement	ODFW	**Management activities including rehabilitation** and **supplementation that increase fish** production beyond **existing** levels, ***[Standard definition needed.]***
evolutionarily significant unit (ESU)	**Suggested standard** **NMFS (Hard et. al.,** 1992)	A population or **group** of populations **that** is considered **distinct** (and **hence** a **"species")** for **purposes** of **conservation** under the Endangered **Species** Act. To qualify **as an ESU, a population** must 1) be **reproductively** isolated **from other conspecific populations, and** 2) **represent** an **important component** in **the** evolutionary legacy of the **biological species (Waples, 1991).**
family **size**	**Suggested** standard **(Kapuscinski,** 1991)	**The** number of **progeny, from** one **female** or one ❑ ale **parent, that survive** to reproduce themselves,
fibs	**Suggested standard (Kapuscinski,** 1991)	A **measure** of reproductive **success** of **an individual** that **is influenced** botb by **survival and fertility; the** frequency distribution of **reproductive** success for a **population** of **sexually** mature adults.
	NMFS (Hard et. III., **1992)**	An individual's contribution, relative to **other individuals,** to **the breeding population** in **the** next **generation. Measures** of **an** animal's **reproductive success** sack as its survival, **fertility,** and age of reproduction are typically used as **indicators** of **fitness. The fitness** of a group **of** individuals **(e.g.,** a population) may be **defined** as **the group's** ability to ❑ aiatala itself **in** its **environment.** It **is therefore** a composite measure of individual reproductive **success.**

Table 1, Definitions of key terms relative to artificial propagation and natural populations in the context of the Endangered Species Act.

TERM OR PHRASE	AGENCY ATTRIBUTION OR SUGGESTED STANDARD USAGE	DEFINITION
foreign	ODFW	Fish which originate through human intervention from a different population [*Standard definition needed.]*
gene	Suggested standard (Kapuscinski,1991)	The basic chemical unit of hereditary information that is passed from parent to offspring. Three claw of genes include: structural genes, regulatory genes and genes ceding for molecules (transfer RNA or ribosomal *RNA)* involved in protein synthesis.
	WDF	[Genes are] individual elements located on chromosomes which carry genetic information for specific biological traits,
genetic diversity	Suggested standard (Kapuscinski, 1991)	AB of the genetic variation within a species. Genetic diversity includes both genetic differences between breeding individuals in a population (within stocks) and genetic differences between breeding populations (between stocks).
genetic drift	Suggested standard (Kapuscinski, 1991)	Random changes in allelic frequencies due to natural sampling errors that occur in each generation; the rate of genetic drift increases as the effective population size decreases.
	NMFS *(Hard* et. al., 1992)	The stochastic process of genetic change through random shifts in allele frequencies. These changes can lead to loss (or, alternatively, fixation) of alleles. Genetic drift con eliminate gene polymorphisms and thereby erode genetic variability, end its effects are greatest in populations of small sii,
genetic resources	Suggested standard (Kapuscinski, 1991)	Identical to the definition of genetic diversity, "all of the genetic variation within a species, etc."
	ODFW	The kind and frequency of genes found within a population or collection of populations.
genetic variation	Suggested standard (Kapuscinski, 1991)	AB of the variation due to different alleles and genes in au individual, population or species; includes variation in alleles and genes influencing qualitative traits (under single gene control) and quantitative traits (under polygenic control).
genotype	Suggested standard (Kapuscinski, 1991)	The set of alleles for one or more genes in an organism; the entire set of genes carried by an individual,
	WDF	The genetic constitution of an individual,
	ODFW	The kinds of and combination of genes possessed by an individual.
goal	Suggested standard (ODFW)	*A* statement of intent which leads to policy, rules and operation plans for implementation of a Departmental Program.

Table 1. Definitions of key terms relative to artificial propagation and natural populations in tbe context of the Endangered Species Act,		
TERM OR PHRASE	AGENCY ATTRIBUTION OR SUGGESTED STANDARD USAGE	DEFINITION
hatchery stock or **batchery fish**	Suggested **standard (Kapuscinski,** 1991)	[A butchery stock is] **a group** of **interbreeding fish** that **are artificially propagated in a hatchery setting** and for **whom the breeding history** of **ancestors** may or may **not** be **known.**
	ODFW	[A **hatchery fish** is] **a fish** incubated or **reared under artificial conditions** for **at least** a portion of its l i f e .
	IDFG	Hatchery **fish are sustained** by some **degree** of **artificial production, generally** for several **generations. They are** released and **return as** adults [to the **hatchery]** for **spawning and subsequent artificial** production of **their progeny.** Genetic material is likely differmt **from native and natural broodstock** of **the** production area because of the **influences** of **artificial rearing** on genetic **selection.** Or, behavior may be different due to **adaptation** to **the hatchery environment.**
inbreeding	Suggested standard **(Kapuscinski,** 1991)	Tbe mating of related **individuals.**
inbreeding depression	**NMFS (Hard** et, al,, 1992)	A reduction **in fitness resulting from** mating **between** close **relatives that occurs** by **chance** in **small populations** or by **assortative** mating in **large** populations. **Inbreeding depression** is **a** consequence of **the expression** of deleterious **recessive alleles as homozygosity increases; therefore,** it **depends largely on dominance,** or **interactions between** alleles **within** loci **(Falconer,** 1981; **Lynch,** 1991). ***[Standard defInltion needed.]***
indigenous	· ODFW	Descended **from** a population **that is** believed to **have been present in the** same **geographical** area prior to **the** year **1800** or **that resulted** fmm a natural **colonization from another indigenous population.** *[Standard defInltion needed.]*
introgression	**Suggested standard (NMFS;** Hard et, **al.,** 1992)	Incorporation of **genetic material** fmm **one gene** pool into **another** by hybridization or **crossbreeding,** followed by V **between crossbred individuals and fish** from the **parental population(s).**
jeopardy (**ESA** context)	**Suggested standard (NMFS; Hard et. al.,** 1992)	**The** National Marine **Fisheries** Service and the **U.S. Fish an Wildlife** Service **have defined** the **phrase** "jeopardize the **continued existence** of **[a listed species]"** to **mean** "to **engage** in **an action** that **reasonably** would be **expected,** directly or **indirectly,** to **reduce appreciably the likelihood** of **both the** survival and **recovery** of **a** listed **species in the wild** by reducing **the reproduction,** numbers or distribution of **that species" (50** U **402.02).**
listed **species/listed population/listed evolutionarily significant unit (ESU)**	**Suggested standard (NMFS: Hard et. al.,** 1992)	For **Pacific salmon, any** ESU **that has been determined** to be **threatened** or **endangered** under **Section** 4 of **the Endangered Species** Act,

able 1. Definitions of key terms relative to artificial propagation and natural populations in the context of the Endangered Species Act,

TERM OR PHRASE	AGENCY ATTRIBUTION OR SUGGESTED STANDARD USAGE	DEFINITION
management plan	ODFW	"Management Plan" means: a. A plan adopted by the Fish and Wildlife Commission which provides the basic framework goals, policies and objectives for managing a resource, geographic area, watershed (waterbody) or species; and b. Which may include specific information or alternatives relative to how the goals and policies may be achieved, *[Standard definition needed.]*
natural stock or natural fish	Suggested standard (Kapuscinski, 1991)	A group of interbreeding fish that reproduce without the aid of humans and whose ancestors probably include hatchery propagated fish (degree of hatchery fish contribution is known or unknown).
	NMFS (Bard et. al., 1992)	(Natural fish am] progeny of naturally spawning parents (Waples 1991). Natural fish thus spend their entire life cycle (except perhaps for brief periods in conservation facilities such as fish ladders or transportation barges) in natural habitat,
	ODFW	(Naturally spawned fish are] fish produced in the natural environment as the result of natural reproduction without the aid of humans.
	IDFG	Natural fish result from natural spawning, but are either not of native broodstock, or have had opportunity to breed with introduced hatchery fish. Genetic material may be different from native broodstock because of these factors.
objective	Suggested standard (ODFW)	A specific statement of planned results to be achieved by a predetermined date. Attainment of objectives represents measurable progress toward attainment of the broader goal.
outbreeding depression	Suggested standard (NMFS; Hard et. al., 1992)	A reduction in fitness that results from mating between unrelated or distantly related individuals...Outbreeding depression may result from loss of local adaptation (see Taylor, 1991, for a review of local adaptation in salmon) or fmm the breakup of gene combinations favored by natural selection; in the latter case, the effects of outbreeding depression am thought to depend on epistasis, or interaction9 between different loci (Lynch, 1991).
phenotype	Suggested standard (WDF)	The trait IN seen or measured, wkicb is produced by the effects of both the genotype and the environment.
population	Suggested standard (ODFW)	,.,a group of fish spawning in a particular area at a particular time which do not interbreed to any substantial degree with any other group spawning in a different area or in tbe same area at a different time.
recovery/restoration (ESA context)	Suggested standard (NMFS; Hard et. al,, 1992)	The reestablishment of a threatened or endangered species to a self-sustaining level in its natural ecosystem (i.e., to the point where the protective measures of the Endangered Species Act am no longer necessary).

Table 1. Definitions of key terms relative to **artificial** propagation and **natural** populations in the contest of the **Endangered Species Act.**

TERM OR PHRASE	AGENCY **ATTRIBUTION** OR **SUGGESTED STANDARD** USAGE	DEFINITION
recovery program	Suggested standard **(NMFS;** Hard et, al,, 1992)	A strategy for the conservation and **restoration** of a **threatened** or **endangered species.** An **Endangered Species** Act **recovery** plan **refers** to a plan **prepared** under **Section 4(f)** of the Act **and approved** by the Secretary, **including** 1) a **description** of **site-specific management** actions **necessary** for recovery, 2) objective, measurable **criteria** that can be used as **a basis** for removing tbe **species** fmm **threatened** or endangered status, and 3) estimates of the time and cost **required** to **implement** recovery, (For **Pacific** salmon, **"Secretary" refers** to the **Secretary** of Commerce,)
rehabilitation	**ODFW**	**Short-term** management actions which may **include fish stocking,** habitat **improvement,** harvest **management,** or other work, that restore **fish populations depressed** by natural or man-made events, ***[Standard definition needed.]***
rehabilitation full	ODFW	A **fish** from a **hatchery** program that **has** wild-type **phenotypes** and is **used** for one life cycle in a program to rebuild **a depressed population** of **wild fish. *[Standard definition needed.]***
regulatory gene	**Suggested** standard **(Kapuscinski,** 1991)	A gene whose function is to **control** the transcription (the **synthesis** of **proteins** coded for in the base pair sequence of DNA in structural **genes]** of other **genes.** Regulatory genes do not code fur **synthesis** of a **specific** protein.
self sustaining population	Suggested **standard (NMFS;** Hard et, **al.,** 1992)	A population that perpetuates itself in the **absence** of (or despite) human **intervention,** without chronic **decline,** in its natural ecosystem, A **self-sustaining population maintains** itself at a **level** above the threshold for listing under the **Endangered Species Act...self-sustaining** and **viable** are used **interchangeably.**
species **(ESA** contest)	**Suggested** standard **(NMFS;** Hard **et. al.,** 1992)	Any subspecies of fish or **wildlife** or plants, **and** any distinct **population** segment of any **species** of **vertebrate fish** or wildlife which **interbreeds** when mature **(Endangered** Species Act, **Sec. 3(15)).** For **Pacific salmon,** this **includes any** distinct **population segment** that **meets** the **qualifications** of an **ESU (Waples, 1991).** A **listed species is** one **determined** to be threatened or **endangered** under the **Endangered Species** Act,
species (taxonomic)	Suggested standard **(ODFW)**	A **group** of **fish** that have **been assigned** a name in the from of genus and **species** by the **American Fisheries Society** Committee oo Common and **Scientific** Names of Fishes,
stock	ODFW	Au aggregation for **management purposes** of **fish** populations which **typically** share common **characteristics such** as life histories, migration **patterns,** or habitats, ***[Standard definition needed.]***
stray	**ODFW**	A **hatchery fish** that spawns naturally in **a** location **different from** the **location intended when the fish** was stocked, ***[Standard definition*** needed.]
structural gene	**Suggested standard (Kapuscinski,** 1991)	A gene **that codes** for formation of a **specific** protein,

Table 1, Definitions of key terms relative to artificial propagation and natural populations in the context of the Endangered Species Act,		
TERM OR PHRASE	AGENCY **ATTRIBUTION** OR SUGGESTED STANDARD USAGE	DEFINITION
supplementation	suggested **standard** (RASP, 1993)	***Supplementation is the use of artificial propagation in the attempt*** to ***maintain or increase natural production*** while **maintaining** the long **term fitness** of **the target population and keeping the ecological and genetic** impacts **on non-target populations within specified biological limits**
	NMFS (Hard et. **al.,** 1992)	**The use** of **artificial** propagation to **reestablish** or **increase** the **abundance** of **naturally reproducing populations (c.f. recovery/restoration).**
	ODFW	**Continued** planting of **fish** to **maintain** or **increase fish abundance in areas where** natural production **is insufficient** to **meet management** objectives,
take **(ESA sense)**	**NMFS (Hard** et. **al.** 1992)	To **harass, harm,** pursue, **hunt, shoot,** wound, kill, trap, **capture** or **collect,** or to attempt to **engage in such** conduct **(Endangered Species** Act, **Sec. 3(18)).**
wild stock	Suggested **standard (Kapuscinski,** 1991)	**Fish that have maintained successful natural reproduction and are known** to **have had** little or no **supplementation from hatcheries in** past **generations.**
	ODFW	**"Wild fish" means any naturally spawned fish in the taxonomic classes Agnatha, Chondrichthyes, and Osteichthyes, belonging** to **an indigenous population.**
	IDFG	**Wild fish are native fish which** have no **history** of **hatchery** or **non-native fish outplanting** or **supplementation,** or **a** limited **amount unlikely** to **have** bad **genetic impact. Wild fish sustain** themselves **as** ml **interbreeding, isolated unit through natural production. Their genetic makeup is assumed to** be **similar** to or evolved **from ancestral** broodstock by **natural selection.**
wild-type phenotype	ODFW	**The** kiud of **phenotype possessed** by **individuals in a** wild **population.** ***[Standard definition needed.]***

2. BIOLOGICAL CONSTRAINTS ON SUPPLEMENTATION

There are three general classes of adverse biological impact to which restorative supplementation is vulnerable: genetic, experiential and ecological. For supplementation to be a success, all three types of impact must be minimized.

As described previously, recovery of a listed stock entails the retention of the genotypes that embody the evolutionary legacy of the stock. Similar considerations apply to borderline listable stocks. Thus a supplemented population must retain a ***large measure*** of its genetic variability and distinctiveness. This is so not only because a loss of within- or between-stock variability, or artificial selection, can be expected to decrease fitness and increase the already high probability of extinction; but because the unique adaptive gene pool the Act was written to preserve will have otherwise been destroyed directly, before the physical elimination of the population.

In the sense in which it is used here, "experiential" constraints refer to non-genetic factors such as physiological conditions of the hatchery reared fish that affect their ability to bolster natural production and promote numerical viability of the targeted stock. Experiential effects are expressed through "post-release survival", and "reproductive success". Post-release survival, the proportion of hatchery reared smolts that survive to adulthood, can be analyzed as the product of a series of life-stage-specific survival rates (survival through the subbasin, through the mainstem Snake/Columbia, through estuarine rearing, and through maturation in the ocean). Reproductive success, here defined as the number of smolts produced per spawner, is also the product of a series of rates: mean eggs per female, pre-spawning survival, proportion of adult recruitment homing to correct drainage and to quality spawning areas within the drainage, proportion of effective spawners (re. mate acquisition, redd digging ability, spawning timing and egg retention)., and survival of progeny across significant life stages (egg-to-fry, fry-to-presmolt and presmolt-to-smolt). All of these rates for a supplemented population are subject to genetic, ecological and "experiential" modification. ***Experiential*** impacts consist of a list of cultural practices that can alter behavior, physiology and morphology of supplementation fish directly, without genetic mediation.

Ecological constraints also affect the ability of the population to attain numerical viability, but the mechanism is mediated by abiotic and biotic environmental factors, not cultural practices. The discussion on ecological constraints will highlight habitat conditions and inter- and intra-specific interactions that could prevent increases in post-release survival or reproductive success for a depressed supplemented population.

The general biological uncertainties associated with supplementation were reviewed by the RASP group (RASP, 1993) and is reproduced in Table 2 below. This list was based on Steward and Bjomn's (1990) exhaustive synthesis of published literature related to the supplementation of salmon and steelhead. Aided by the perspective provided by Table 2, the reader wishing a more detailed exposure to the broad biological underpinnings of supplementation should consult the original document.

Table 2. Genetic, ecological and experiential uncertainties associated with supplementation (adapted from **RASP, 1993)** .

UNCERTAINTY TYPE	UNCERTAINTY
The "central uncertainty" **(SRG, 1990).**	Under what set of conditions will **supplementation** of natural and wild production with hatchery production add to the total production of salmon, steelhead or other targeted fishes over the long term?
Genetic	1. Biochemical techniques for stock separation are not **always conclusive** and the genetic **basis** for the observed variability in stocks of Pacific **salmon** is not well documented.
Genetic	2. It is not known whether some species or races of **salmon,** or life histories within species, are better suited to supplementation than others.
Genetic	3. It is not known whether domestication and loss of performance in the wild is an inevitable consequence of artificial propagation. The hinds of hatchery environments and practices that preserve natural adaptations in hatchery-reared **fish** are unknown.
Genetic	4. The impact of the use of foreign or distant broodstock on **smolt-to-**adult survival and fitness is unknown. A closely related uncertainty is the magnitude of outbreeding depression and the consequences of losing co-adapted complexes in **wild** stocks when exogenous stocks are used.
Genetic	5. The ***amount*** of information on genetics, life history, ecological characteristics and interactions of hatchery and wild stocks **necessary** to employ artificial ***selection*** safely and beneficially in supplementation is unknown. Put another way, can "remedial selection" in a hatchery ever be **safely** and **beneficially** employed on stocks that have already lost genetic variability or are poorly adapted to the modern environment?
Genetic	6. The rate at which hatchery-reared **fish** adapt to natural environments is unknown. A related uncertainty with major implications for supplementation is the number of natural generations required before offspring of hatchery-reared parents achieve the fitness of the wild stock.
Genetic	7. The conditions under which ***beneficial gene flow*** from hatchery to wild stocks occurs are unknown.
Genetic	8. The maximum ratio of hatchery to wild spawners to ensure minimum deleterious genetic impacts is unknown. The minimum acceptable effective population size for hatchery breeding and natural spawning is unknown.
Ecological	1. The environmental conditions (dam mortality, habitat degradation, etc.) under which supplementation will fail to achieve its goals -- even. when hatchery **fish** are genetically equivalent to wild **fish --** are **unknown.**

Table 2. Genetic, ecological and experiential uncertainties associated with supplementation (adapted from RASP, 1993) .

UNCERTAINTY TYPE	**UNCERTAINTY**
Ecological	*2.* It is not known whether interspecific competition or predation can prevent a depressed population from responding to **supplementation.** A related uncertainty concerns the impact of multiple stability regions. Assuming that multiple **stock-recruitment** stability regions exist, and that some populations are **"trapped"** in a lower region because of interspecific competition or predation, what combinations of hatchery release numbers and reductions of competitor ***or*** predator populations will allow the target population to **regain** its higher equilibrium level?
Ecological/Experiential	1. The **effects** of hatchery practices on survival and production are unknown. For example, the combinations of release size, time, and density which stimulate natural production without displacing wild **fish** are unknown; the life stage and season of stocking that **minimize** hatchery-induced impairment of predator avoidance and feeding **efficiency** are **unknown;** the degree to which behavior learned in a hatchery predisposes **fish** to higher rates of predation, lower feeding efficiency, or suboptimal habitat use is not known; and the degree to which improved hatchery practices (sire and time of release, disease prophylaxis, reduced rearing density, **etc.)** can improve early marine survival is unknown.

2.1 PURPOSE, SCOPE AND METHODS

The purpose of the following discussion on biological constraints is to highlight biological factors of particular relevance to depressed and declining stocks for which supplementation is contemplated. Moreover, because in this report the targeted population represents an ESU or a potential ESU, discussion will be limited to scenarios in which the broodstock source is the ESU itself. An additional purpose is to provide a context and rationale for the categories used in a subsequent section to analyze institutional constraints on restorative supplementation. Most of the material in this section was drawn from two sources: Steward and Bjornn (1990) and RASP (1993) and an unpublished analysis of genetic constraints written for the Yakima/Klickitat Production Project by Dr. Craig Busack of the Washington Department of Fisheries.

2.2 GENETIC CONSTRAINTS

2.2.1 Introduction

Concern for the conservation of fish genetic resources currently plays a large and growing role in the management of fish populations, particularly management of salmon and steelhead stocks of the Pacific Northwest. This concern was recently underscored at a series of genetic conservation workshops held by the Northwest Power Planning Council. The consensus of the workshop geneticists was that a sustainable increase in the productivity of Columbia basin salmonids cannot be achieved without conservation of the genetic resources in these stocks. Genetic conservation and the Council's goal of doubling salmon and steelhead production in the Columbia basin are thus inextricably intertwined.

2.2.2 Extinction

Type 1 risk, extinction, represents the most extreme type of risk. Once a population is extirpated, all its genetic variability is irretrievably lost. Any genetic uniqueness represented by that population is gone.

2.23 Loss of Within-population Variability

The second type of risk, loss of within-population variability, is commonly associated with hatchery production. There are three categories of Type 2. Type 2a risk is loss of variability due to genetic drift, a problem common to all finite populations. If the population is large enough, this loss through drift is compensated for by the creation of new variability by mutation, but captive populations are generally too small for this compensation to occur. The result is a gradual loss of variability and concurrent increase in homozygosity. Since genetic variability is the raw material upon which selection acts, this loss in variability becomes a loss in responsiveness to natural selection. Population fitness will suffer. Loss of variability is related to effective population **size** (Table 1) rather than census population size.
Type 2b risk is loss of variability due to nonrandom sampling of a population in collecting broodstock. Significant portions of the stock's genetic variability may thus be omitted from the cultured stock. This phenomenon is often called founder effect.

Type **2c** risk is loss of genetic variability due to very strong selection. Normally, selection is thought of as modifying allele frequencies slowly, but very strong selection can cause rapid changes in frequency, resulting in a loss of variability. This subcategory of risk is discussed further below in the material on type 4 risk.

There is an important difference between Type 2a and the other subtypes. Type **2a** risk refers to systemic loss of genetic variability; i.e., variability not restricted to specific traits. Types 2b and **2c,** on the other hand, primarily involve genetic variability associated with specific traits.

2.2.4 Loss of Between-population Variability

The third type of genetic risk is loss of between-population variability, which can also be described as loss of population identity. If two populations are mixed, there may be no loss of genetic material overall, but the genetic distinctness of the two populations, based on the genes they separately contained at particular frequencies, will be lost.

A special case of the loss of between-population variability is the loss of co-adapted complexes through introgression of distantly related populations and a subsequent loss of fitness by "outbreeding depression" in the F2 generation. "Co-adapted complexes" are gene combinations the naturally occur together in all or most individuals in a natural population because of their collective adaptive value. Theoretically, outbreeding depression does not express itself until the F2 generation because F1 fish each have complete sets of each complex in their maternal and paternal alleles. The mixing occurring in meiosis when F1 fish reproduce results in a random shuffling of maternal and paternal alleles, and F2 fish are therefore virtually certain of losing a complete set of either complex. It should be noted that the occurrence of co-adapted gene complexes and their relevance in environments highly altered by human activities (e.g., many parts of the Columbia River Basin) is not yet well documented in salmon and steelhead (Allendorf et al., 1990).

2.25 **Artificial Selection/Domestication**

A fourth type of genetic risk, domestication selection, needs to be considered in assessing the impact of hatchery operations on salmon and steelhead. Hatcheries, despite attempts to avoid causing genetic change in the cultured stock, may impose new selection regimes on the fish in the course of standard fish culture techniques, causing increased fitness in the hatchery environment, but decreased fitness in the wild.

A distinction needs to be made here between Type 4 risk and Type 2c risk. Type 4 risk refers to gradual change that may change the population's genetic composition, but not changes accompanied by a appreciable reduction in variability. Both types of impact may change the population's prospect for future change, but a Type 2c impact would be more severe.

Mention should also be made of a special case of artificial selection which so far exists only as a theoretical possibility: "latent" artificial selection. This type of selection might result from the fact that natural selection on hatchery fish is deferred until fish are released. As Waples (1991) points out, only if this delayed selection removes the same genotypes that naturally would have been removed earlier will the cultured fish be genetically equivalent to their natural counterparts.

2.2.6 **Strategies for Genetic Conservation**

There are four basic strategies for conserving genetic resources. These strategies are: 1) identification of substocks present; 2) separate culture of substocks and release only into native stream areas; 3) marking of all hatchery-produced fish; and 4) use of naturally produced fish as much as possible for broodstock, thus ensuring a cycling of hatchery fish through the natural environment. Another key element is a set of comprehensive genetic hatchery guidelines for maximizing effective size and minimizing domestication selection. The guidelines should encompass all aspects of hatchery operations, from broodstock collection to release.

2.2.7 **Cultural Activities with Genetic Impacts**

Five cultural practices in a supplementation program can impact genetic resources in a supplemented population directly, and one can have indirect impacts. The five practices with direct impact are choice of broodstock source, the number and kind of adults mated, fertilization protocols, rearing practices, and size of donor stock remaining for natural reproduction. The practice with indirect impacts is the geographic distribution, timing and relative magnitude (re. the size of the wild population) of the release. Kapuscinski (1991) outlines the general avenues of genetic interaction as follows: "Broodstock management and rearing activities may alter genetic resources and life history patterns of hatchery stocks. In turn, hatchery-released fish may alter genetic resources and life history patterns of wild or natural stocks via interbreeding. Wild stocks may be genetically altered if excessive numbers of adults are removed to supply gametes for hatchery stocks. Indirect genetic impacts are also possible if large numbers of hatchery fish enter into behavioral or ecological interactions with wild or natural stocks."

It is obvious that an inappropriate choice of donor stock represents a clear and present danger to the maintenance of population identity, and that this threat will be realized as soon as hatchery and wild fish interbreed. Fertilization protocols, especially the way in which multiple egg lots are mixed with sperm from a number of males, can affect the effective size of the hatchery population if provisions are not made to ensure all males have equal opportunity to fertilize equivalent numbers of eggs and contribute to the next generation (Type 2 impact). A sharp reduction in within-population variability and effective size can result from mating strategies that entail unbalanced sex ratios, insufficient numbers of breeders, and a skewed subsample of breeders with respect to heritable traits of adaptive significance (size, age, run timing, spawning timing, etc.). Selective breeding, of course, directly reduces within-population variability by directed selection. Rearing presents a multitude of opportunities for selection against heritable traits of adaptive significance in nature. Among the most prominent: thin-outs or grade-outs of slower growing or later spawned fish; the mixing of fish of different age and size such that the latter are outcompeted for food in the hatchery and either die there or after release because of a persistent size disadvantage; and a multitude of more subtle inadvertent selective impacts on feeding, cover usage, predator avoidance, etc., that are generally referred to as domestication. [Note, however, that many of impacts commonly attributed to domestication may in fact have a behavioral etiology.] The size and composition of the donor stock remaining for natural reproduction presents a Type 2 concern that is the mirror image of the selection of the number and type of adults mated in the hatchery. There are, in addition, qualitatively distinct impacts on the effective size of the supplemented population.

One basic element of genetic strategies that does need additional discussion is the issue of what proportion of the wild population can be taken initially into the hatchery. Explaining this requires a lengthy discussion, but it is worthwhile to include it here, as the basic concepts apply to all species, and it is an important issue. The potential impact of broodstock collection on N_e has been known in an intuitive sense for years. If some fish from a population are taken into the hatchery, and hatchery fish have a higher survival than wild fish, then the adults taken into the hatchery will as a group leave more progeny than the adults not taken into the hatchery, depressing the effective population size. Recently, however, Ryman and Laikre (1991) developed an equation to explicitly express the impact on N_e of a situation like this. If N_H and N_W are the effective sizes of the fish taken into the hatchery and those left to spawn in the wild, and x is the proportion of the returning progeny descended from the fish taken into the hatchery, the resulting **N2$_e$ of** the composite population is given by

$$\frac{1}{N_e} = \frac{x^2}{N_H} + \frac{(1-x)^2}{N_W} \qquad \text{Eq. (1)}$$

Ryman and Laikre developed this equation for the simple case of hatchery production being used to produce a harvestable surplus while maintaining the same escapement as before the hatchery operation began. This clearly is not the case for restorative supplementation, where we want to use hatchery operations to increase the size of the spawning population. How to incorporate population growth into the **Ryman** and Laikre equation is presently unclear, but work is continuing. In the meantime, it seems reasonable to assume that the results for growing populations will not be appreciably different from those for stable populations.

In applying the R&L equation to restorative supplementation, we have reformulated it to apply it generically to broodstock collection from small escapements. We begin. by making the assumption that

$$N_e = N_H + N_W \qquad \text{Eq. (2)}$$

In terms of management, this means that sex ratio perturbations and expected variance in family size in the wild and hatchery groups are the same. The number of adults taken into the hatchery and left in the wild can be now expressed as proportions of the total:

$$N_H = pN_e \qquad N_W = (1-p)N_e \qquad \text{Eq. (3)}$$

Note also that the proportion of returning progeny produced by these hatchery adults can be expressed as

$$x = \frac{sN_H}{sN_H + N_W} \qquad \text{Eq. (4)}$$

where **s** is the survival of hatchery progeny to adulthood relative to that of wild progeny.

With these simplifications done, the R&L equation can be restated in terms only of the proportion of adults taken into the hatchery **(p)** and the survival of hatchery fish relative to wild (s):

$$N_e^1 = \frac{N_e^0(sp+1-p)^2}{s^2p+1-p} \qquad \textbf{Eq. (5)}$$

where $\mathbf{N_e^0}$ and $\mathbf{N_e^1}$ are the original and resulting effective sizes, respectively. Dividing through by the original $\mathbf{N_e}$ gives the resulting $\mathbf{N_e}$ as a proportion of the original **($\mathbf{N_{ep}}$)**:

$$N_{ep} = \frac{(sp+1-p)^2}{s^2p+1-p} \qquad \textbf{Eq. (6)}$$

This is an important result. The **proportionate** reduction in $\mathbf{N_e}$ is a function only of p and s, not of the original $\mathbf{N_e}$. The decrease in $\mathbf{N_e}$ for varying p and s is shown in Figure 2. The maximal decrease in $\mathbf{N_e}$ for a given s appears to be achieved at

$$P = \frac{1}{s+1} \qquad \textbf{Eq. (7)}$$

The message of the material above for rules regarding the maximum permissible percentage of the run to be taken into the hatchery is obvious: there is no single correct value for the maximum acceptable percentage to be used as broodstock. Each case has to be evaluated separately in light of the relative survival advantage expected to be realized from the hatchery, and the risk of catastrophic loss in the hatchery.

One interesting result of the R&L equation, especially as shown in Figure 2, is that for purposes of maintaining $\mathbf{N_e}$, a good strategy is to take all or most of the fish into the hatchery. The greater the hatchery survival advantage, the more attractive this strategy becomes. Although this strategy seems like a good idea for dealing with this one aspect of genetic conservation, there are other considerations which argue against it. The risk of domestication selection and catastrophic loss are increased as the percentage taken into the hatchery increases. The risk of hatchery operations is uncertain in general, but could be quantified by reviewing hatchery records of basin management agencies.

The foregoing material assumes a simple, non-overlapping age structure (discrete generations), and furthermore assumes that $\mathbf{N_e}$ can be measured and s predicted well. Most anadromous salmonids have overlapping age structures, and we have limited ability to measure $\mathbf{N_e}$ and predict s. The more complex age structure means that the effective number of breeders **($\mathbf{N_b}$)** in a given year must be considered rather than N,. $\mathbf{N_e}$ is approximately the product of the mean $\mathbf{N_b}$ and the generation length (average age at spawning) (Waples 1991). $\mathbf{N_b}$ can be substituted for $\mathbf{N_e}$

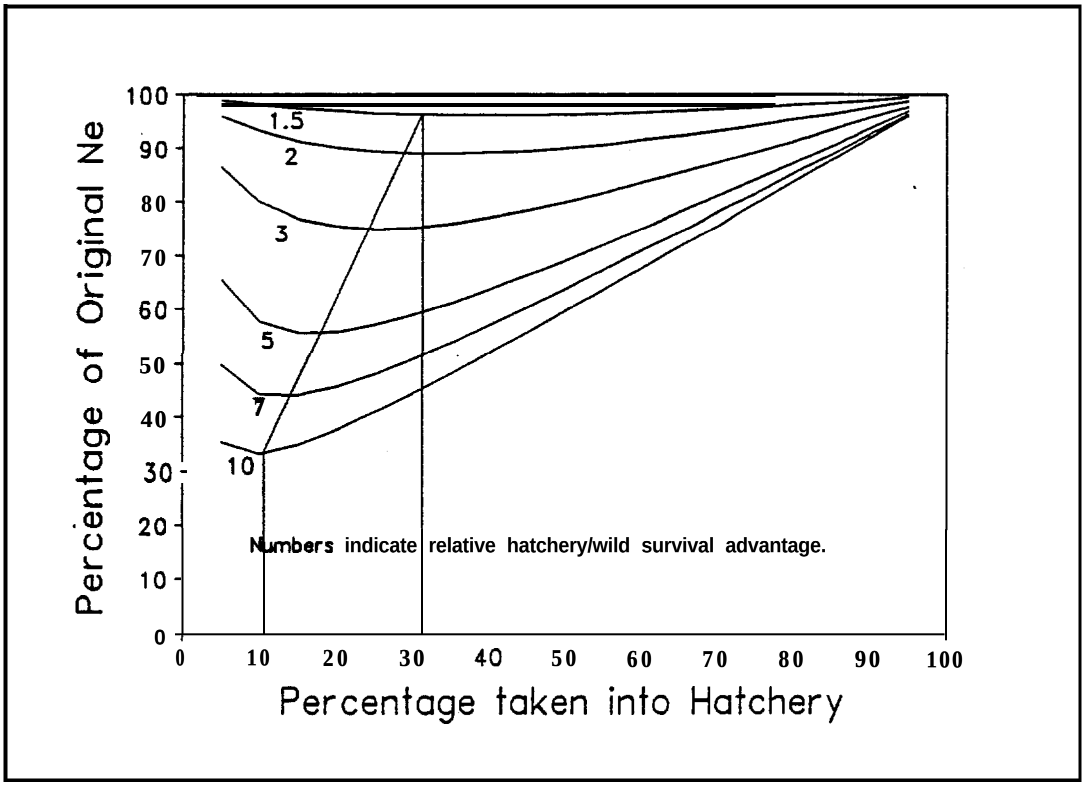

Figure 2. Depression of original effective population size as a function of percentage natural population taken into hatchery and relative hatchery/wild survival advantage. (Figure and analysis courtesy of Craig Busack, WDF.)

throughout the equations above. Our inability to measure $\mathbf{N_e}$ or $\mathbf{N_b}$ with high accuracy is not in general a serious problem, because the proportionate reduction is independent of effective size. However, it is desirable to have a "ballpark" estimate of $\mathbf{N_e}$ or $\mathbf{N_b}$. A 12% reduction, for example, is not a serious matter if $\mathbf{N_e}$ is 500, but is if $\mathbf{N_e}$ is 50. Estimation of s is likely to continue to be a chronic problem. A strategy attempting to find a relatively s-insensitive proportion leads only to the two extreme cases, taking virtually all or virtually none of the fish.

2 3 ECOLOGICAL CONSTRAINTS

23.1 Density-related Environmental Constraints

2.3.1.1 Introduction

Strictly on logical grounds, there are a limited number of situations for which restorative supplementation is appropriate. Successful supplementation presupposes minimal density-dependent limitation on production through the freshwater juvenile portion of the life history (egg to smolt). Extra spawners, even if they are genetically, behaviorally and physiologically identical to indigenous fish, will not meaningfully increase the production of natural smolts if the capacity of the environment to support fish is already heavily taxed. It is, on the other hand, at least theoretically possible for an ideal supplementation program to be effective when natural production is limited primarily by high, density-independent mortality, regardless of the life stage at which it occurs. But even in the latter ***case, sustained*** effectiveness requires either that supplementation itself be sustained, or that the impact of the density-independent mortality factors be reduced. These common-sense notions imply that ***restorative supplementation*** is only appropriate for stocks inhabiting significantly underseeded streams, or streams for which capacity can be significantly increased. The ESA requirement that targeted stocks become self-sustaining (i.e., that the population maintain itself without supplementation) also implies that restorative supplementation must always be accompanied by some type of "habitat enhancement" which reduces the magnitude of density-independent mortality.

The preceding paragraph was intended to demonstrate that some form of ***limiting factors analysis*** must precede the design of any supplementation program, "restorative" or otherwise. Accordingly, rather than recount the multitude of biotic and abiotic environmental factors that might compromise or facilitate supplementation, the focus of this section will be on describing the essential elements of "pre-supplementation limiting factors analysis".

2.3.1.2 Patient/Template Analysis

The RASP group (RASP, 1993) developed a five-step approach to limiting factors analysis they termed "Patient/Template analysis" (PTA). The approach and method of PTA is fundamentally "clinical": a "healthy" historical stream/stock system-the Template-is contrasted with a dys-functional contemporary system-the Patient-in order to diagnose and treat the causes of depressed production. This approach assumes that the patient system cannot be cured without knowing what health looks like locally.

Before the five substantive steps can be described, some background must be provided. Conceptually, PTA can be reduced to three propositions:

1. A population is an aggregate of discrete life histories.

2. A life history is series of seasonally and geographically connected places which support all life stages in the natural life cycle.

3. A life stage is a discrete developmental phase, such as egg to emergent fry, emergent fry to late-summer **parr,** late-summer parr to late-winter pre-smolt, smolt, etc.

PTA makes rather special use of the term “life history”. At its finest level, a life history is a group of fish within a genetically discrete population (e.g., an **ESU)** whose life cycle describes a unique “trajectory” in space and time. **Salmonid** life histories have evolved to take advantage of seasonal and spatial variations in resource availability, and a diversity of life history types serves to buffer the population against environmental unpredictability. Each life history type is a succession of life stages that collectively describe a unique pattern of movement and distribution within the environment. If critical habitats are destroyed or degraded within relatively short periods, the affected life histories are not likely to persist within the matrix of life histories that comprises the population.

The PTA approach requires that life history types be broken down into a network of ecologically discrete life stages so that the capacity of the environment to support each stage can be determined “Ecological discreetness” refers to a combination of resource requirements that are unique to a particular developmental stage. The juvenile freshwater portion of a typical spring chinook might, for example, be decomposed into four ecologically discrete life stages: incubation, summer rearing, winter rearing and smolting.

Life history types differ when one or more of their constituent life stages use different geographical areas or, if found in the same areas, use them at different times. Freshwater, estuarine and marine habitats should be stratified into environmentally homogenous spatial units having more-or-less unique habitat characteristics; An analysis based only on juvenile freshwater life stages is thus incomplete, but also extremely valuable because, as mentioned above, supplementation is impossible when production in the targeted system is irremediably limited by density-dependent factors.

Therefore the minimum acceptable scope for PTA is the freshwater juvenile life stages. In performing such an analysis, it is possible, provided sufficient data, to subdivide the freshwater environment into distinct environmental strata, or “habitat units”, on the basis of thermal cycles, **instream** flow and hydrographic patterns, channel morphology and gradient, substrate character, **riparian** condition, densities of predators and competitors and accessibility. After habitat units have been described, it is useful to represent the environment as a matrix in which rows represent habitat units and columns time periods for discrete life stages. Distinct life histories will describe different lines through such a matrix.

With this background, it is-now possible to describe the five steps of PTA. They are:

1. Describe life histories in Template and Patient.

2. Describe the environmental requirements for each life history by life stage.

3. Estimate existing, potential and historic carrying capacity, as well as existing production, for each density-dependent life stage in each life history in Template and Patient. Estimate historical and existing survival rates for density-independent life stages.

4. Identify the life stage at which each life history is limited and the mechanism of limitation.

5. Identify actions to remove or lessen the severity of limiting factors.

Steps 3 and 4 refine the description of Template and Patient through quantitative analyses. Step 3 requires that life stages be classified as density-independent or density-dependent. For density-dependent stages, carrying capacity is estimated for historical, potential (or achievable) and existing states. Historical capacity refers to pristine production. Potential capacity refers to production under anticipated future conditions, usually involving some form of habitat enhancement. Existing capacity is the capacity of the existing, unimproved habitat.

Existing production by life stage is estimated in Step 3 as the product of mean density by habitat unit and habitat unit area summed over all classes of habitat unit. The ratio of existing production to existing capacity (the "utilization index") provides an initial, rather crude insight into the causes, location and timing of production limitations (a more sophisticated but data-intensive procedure is described below). The ratio of existing to potential carrying capacity indicates the degree to which problems might be resolved by habitat enhancement. Finally, the ratio of potential to historical capacity indexes the productive capacity that has been irretrievably lost. If a suspect life stage is in fact a limiting phase of a major life history, this latter ratio can be used to gauge the potential benefits of a combined supplementation/habitat enhancement project (expressed in terms of historical production).

Step 3 also requires the an estimate of survival rates for density-independent life stages. The smolt-to-adult portion of the life cycle is usually thought of as density-independent, in terms of the effect of an individual population. Smolt-to-adult survival estimates should be compared with maximum utilization indexes to evaluate the feasibility of various enhancement options. If the maximum utilization index and the smolt-to-adult survival rate are both low relative to productive, fully-seeded systems, supplementation is probably warranted; production is limited by low spawning escapement and, all else being equal, the number of spawners should increase in direct proportion to the number of fish outplanted.

Step 4 entails the identification of limiting life stages (in the Patient) and the description of the causes of limitation. High utilization indexes imply the operation of density-dependent factors but by themselves offer little to assist in identifying specific causal mechanisms. Detailed knowledge informed by empirical studies of the stream/stock system is required for this exercise.

The final step in PTA is to design enhancement or restoration programs to resolve or circumvent limiting factors. The selection of an appropriate treatment depends not only on an accurate diagnosis, but on cost, risk, social acceptability and other considerations.

23.13 Relevance to Restorative Supplementation

In the light of this approach to limiting factors analysis, there are (at least) two considerations that planners of restorative supplementation projects should seriously investigate. The first concerns the enhancement of depressed life histories and the second concerns possible synecological consequences of prolonged depression.

2.3.1.4 Enhancing Depressed Life Histories

Populations which have been radically depressed for prolonged periods (which probably includes most listed populations and listing candidates) will probably have suffered a severe loss of life history diversity. However, so long as some individuals remain with the genetic capability of exhibiting life histories which now have vestigial status, there is a possibility that a combination of strategic habitat enhancement and outplantings will “release” one or more life history types, allowing substantial recovery. This possibility is, of course, greater if one or more life histories suffer from a single (perhaps the same) bottleneck.

An important corollary point is that there is value in improving habitat quality for a depressed life history even though the relevant habitat is, by definition, underseeded. Moreover, an improvement in habitat quality for a specific life stage can increase smolt production even when the capacity of a pre-smolt life stage is limited. These somewhat counter-intuitive assertions are based on the fact that freshwater production is determined by a number of density-dependent life stages in succession, each of which is characterized by unique productivity and capacity characteristics. These characteristics interact across life stages in ways that are not immediately apparent.

The truth of this assertion requires consideration of a stock production model parameterized or “disaggregated” by life stage to reveal the effects of changes in individual life stage production parameters. Mousalli and Hillbom (1986) demonstrated that the Beveton-Holt stock production model, assumed to describe most salmon and steelhead stocks (Bjornn and Reiser, 1991), can be parameterized in terms of any number of antecedent life stages which also follow Beverton-Holt dynamics. Production at any life stage is defined as

$$R = \frac{(p*S)}{(1 + (\frac{p}{c})*S)} \qquad \text{Eq. (8)}$$

where R = individuals surviving at the end of a life stage;
S = individuals alive at the beginning of a life stage;
p = productivity parameter (density-independent survival); and
c = habitat capacity for life stage.

The productivity parameter p is considered to be density-independent, and describes stage-specific survival at low population densities. The parameter c reflects density-dependent mechanisms, and represents stage-specific carrying capacity. Productivity is determined primarily by the ***quality*** of the habitat, while capacity is determined primarily by the ***quantity*** of the habitat.

Parameterization of the stock production function is not really necessary to demonstrate the utility of improving the quality (increasing p) of underseeded habitat; Equation 8 and knowledge of the general characteristics of the Beverton-Holt curve will suffice. When habitat is very underseeded, S/c is small and the denominator of the right-hand term of Equation 8 will be close to 1 no matter how large p is. The numerator, however, increases in direct proportion to increases in p. Graphically, the effect of increasing habitat quality is to make the production curve rise more steeply, so that any antecedent population will recruit more survivors to the next life stage. This effect of increasing p will be most pronounced near the origin (at low densities).

Mousalli and Hillborn demonstrate how smolt yield can be expressed in a three-stage model with separate productivity and capacity terms for egg to fry, fry to fall parr and fall parr to smolt life stages:

$$R_3 = \frac{p1*p2*p3*S}{1 + (\frac{p1}{c1} + \frac{p2}{c2} + \frac{p2*p3}{c3})*S} \qquad \text{Eq. (9)}$$

where R_3 = the production of smolts;
p1, p2, p3 = productivities of egg to fry, fry to parr and parr to smolt stages respectively;
S = the number of eggs; and
cl, c2, c3 = capacities of the egg to fry, fry to parr and parr to smolt stages, respectively.

They then demonstrate that in this kind of multistage system, ***cumulative*** smolt carrying capacity is a function of antecedent life stage productivities as well as capacities:

$$C = \frac{(p1*p2*p3)}{(\frac{p1}{c1} + \frac{p1*p2}{c2} + \frac{p1*p2*p3}{c3})} \qquad \text{Eq. (10)}$$

where C = cumulative smolt carrying capacity;
p1, p2, P3 = productivities of egg to fry, fry to **parr and parr** to smolt stages respectively; and
cl, c2, c3 = capacities of the egg to fry, fry to parr and parr to smolt stages, respectively.

Although it is not readily apparent from Equation 9, it can be shown by substituting reasonable hypothetical parameters that smolt yield can be substantially increased by increasing productivities even when one of the capacities is quite low. Furthermore, this effect is most pronounced at low seeding (where seeding is the ratio of composite productivity, **p1*p2*p3**, to cumulative capacity).

Equation 10 demonstrates that smolt carrying capacity varies in relation to the productivities and capacities of antecedent life stages, which is more realistic than the notion of fixed carrying capacity based solely on available habitat. Thus, smolt capacity can be altered by improving either the productivity or capacity of composite life stages.

The basic point of the preceding discussion is that one is unlikely to become aware of any of the potential remedial strategies just described unless a thorough limiting factors analysis with the scope of PTA is implemented.

23.1.5 Consequences of Prolonged Depression

There almost certainly will be ecological consequences to a prolonged decline in abundance of a formerly dominant species. As stated in the RASP Summary Report Series **(RASP, 1993),** "one cannot assume that a stream with a depleted salmon population has vacant habitat equal to the difference between the past and present population sizes. Depletion of an abundant and productive salmon population does not usually create production vacuums...in productive waters, vacant habitat will, in many cases, be colonized by another species/race. Consequently, successful supplementation may displace a population of another species or a resident population of the same species (e.g., steelhead may displace resident rainbow trout). The displacement can have biological, economic and political consequences.

Another possible consequence of prolonged depression is that colonizers may be competitors or predators of the targeted species. It has long been known on a theoretical level that intense competition and predation might be capable of permanently "trapping" a formerly abundant species at low levels of abundance. Competitive shifts have been well documented in marine populations. The northern anchovy became dominant after the collapse of the California sardine, and Atlantic herring dominated after the collapse of the Atlantic mackerel (Skud, 1982). Regarding the marine species, Skud (1982) quoted N. Daan's estimate that it would take a **50%** reduction in the dominant species. and a corresponding increase in the depleted species maintained for several years to reestablish dominance.

There is perhaps more reason to be concerned that a targeted population may have become "trapped" in a "lower stability region" because of heavy mortality attributable to predators that display a Type-III functional response (Peterman, 1977). Until they reach maximum consumption rates, Type-III predators concentrate increasing efforts on a given prey species as it becomes more abundant, but virtually ignore it once its abundance falls below a certain level. A plot of the proportion of the prey population consumed per unit time as a function of prey density (functional response) therefore is sigmoidal. If the maximum prey consumption rate is large enough, and if it occurs at low enough prey densities, simulated Type-III predation causes the stock-recruitment curve to cross the replacement line in three places, trapping small prey populations in a lower zone of stability.

Recently, a number of field observations suggest this "predator trap" may be more than an interesting bit of theory. A Type-III functional response of predators to salmon prey has been documented by Peterman and Gatto (1978), Mace (1983), Wood (1984) and just recently for northern squawfish feeding below McNary Dam (Petersen and DeAngelis, 1992). McIntyre et al (1989) examined records of Karluk Lake, Alaska sockeye that dropped in abundance in the early part of he century from millions to thousands. They developed a stock-recruitment line for this population that showed two equilibrium regions. Peter-man (1987) noted a similar phenomenon for pink salmon in area 8, British Columbia, with one significant difference: the data he examined indicated that the population had apparently entered a higher stability region after three years of heavy supplementation.

Thus, multiple stability regions and "predator traps" should be taken seriously by the planners of restorative supplementation. If such phenomena are suspected, two responses would be appropriate. First, releases should be as large as possible, predator numbers should be reduced and prey protection measures should be implemented. Second, exploitation should be reduced. Exploitation, in effect, makes the population less productive (rotates the replacement line in a stock-recruitment line counter clockwise), and ***increases*** the stock size marking the boundary of the lower stability region.

2.4 EXPERIENTIAL IMPACTS

2.4.1 Experiential Impacts on Post Release Survival

Once begun, one of the most immediate priorities of a restorative supplementation program is to maximize the post-release survival of supplementation fish; the critically depressed and declining status of the stock, and the biotic resources invested in supplementation, do not allow for extensive trial and error. Adding to the urgency is the fact smolt-to-adult survival for hatchery fish reared under conventional conditions is frequently an order of magnitude lower than local natural populations (Raymond, 1988; Fast et. al., 1991), even when these natural populations provide the hatchery broodstock (Fast et. al., 1991). There is a growing opinion that much of the poor relative survival of hatchery-reared fish is attributable to hatchery experiences which adversely impact post-release behavior and physiology directly. Such opinion is corroborated by observations of comparable survival for simultaneously released groups of non-native hatchery and hatchery-reared wild steelhead (Aho, 1979) and spring chinook (Fast et al., 1991).

Because the great majority of mortality in anadromous fish is at least proximately attributable to predation (Steward and Bjomn, 1990), much thought has been directed at determining the ways in which hatchery experiences can, directly or indirectly, exacerbate predatory losses. Considerable attention has also been focussed on foraging behavior of hatchery fish, which numerous studies have shown is often less efficient in nature than that of wild fish (Doyle and Talbot, 1986; Bachman, 1984). Some authors have concluded that the failure of hatchery fish to develop efficient foraging strategies when released increases mortality directly, by starvation, or indirectly, through debilitation, disease and predation. It is important to note that both of these impacts may be mediated largely or entirely by maladaptive conditioning and/or “suppression” of behavior -- by the failure of the hatchery environment to supply appropriate releasing stimuli for instinctual behavior with cascading effects.

Wild-type social behavior may also be suppressed or artificially conditioned in a hatchery environment. Higher levels of aggression (Fenderson et al., 1968), and failure to disperse in response to density dependent cues (Symons, 1969), have been observed in hatchery-reared fish in the wild. Such “social ineptitude” could reduce the survival of supplementation fish released as pre-smolts. In this case as well it has been proposed that predation is the proximal of the relatively higher mortality rates of “socially retarded” hatchery fish, which make themselves more vulnerable by unnecessary agonistic behavior (Swain and Riddell, 1990), or by in effect “chumming” predators to them by their remaining for prolonged periods in dense, conspicuous aggregations. It has also been surmised that excessive expenditures of energy in agonistic behavior lead to death directly, by starvation.

Poor survival of hatchery fish may also be attributable to the physiological and morphological consequences of hatchery rearing. Prominent among physiological concerns is disease. An important and frequently overlooked morphological impact is the degree of cryptic coloration among hatchery fish, especially when they are released as pre-smolts.

It is widely believed that disease is responsible for considerable mortality among hatchery fish after release, either directly or indirectly. The release of hatchery fish with latent, subclinical infections is frequent (Marnell, 1986). An all-too-familiar example is provided by hatchery-reared spring chinook and bacterial kidney disease (BKD). Efforts to control epizootics of BKD among. Columbia Basin hatchery stocks appear to have failed (Elliott et al., 1989), and the disease has come to be regarded as a chronic, and perhaps permanent, feature of spring chinook under artificial propagation. Indeed, many researchers now believe BKD is the major factor limiting production of spring chinook at Snake River hatcheries. BKD infections usually entail little mortality so long as stress is minimized. Unfortunately, significant stressors in the Columbia cannot be avoided; handling and confinement of fish during transportation from the hatchery or at mainstem dams, tagging, passage delays at dams, elevated temperature and pollution all have been shown to elevate stress (Specker and Schreck, 1980; Congleton et al., 1985). Sadly, exposure to seawater is also a significant stressor, one that activates the disease and is capable of triggering heavy (up to 85%) mortalities (Congleton et al., 1985).

2.4.2 Behavioral Impacts

Many of the adverse behavioral impacts of hatchery rearing may be mediated by alterations in patterns of habitat use and a failure to recognize predators. Importantly, these impacts appear to occur for fish reared to the late-par-r or smolt stage (Bjornn, 1978) and, it is hypothesized, under "conventional" conditions.

Opposed to "conventional" rearing is "naturalistic " rearing. The latter has been proposed as a remedy for dysfunctional adaptations to the rearing experience in conventional hatcheries. The intent of naturalistic rearing is to duplicate (as yet unknown) essential features of the natural environment so that, by one theory, fish have the opportunity to learn (by instrumental conditioning) appropriate behavior (D. Maynard, NMFS, 1992, comments made at YKFP Project Annual Review) or, by another, to experience the stimuli necessary to release instinctual wild-type behavior during critical developmental periods (T. DeVietti, Central Washington University, personal communication, 1992).

Although the essential features of the natural rearing environment have not been determined, there is some consensus on possible elements. The Artificial Environment/Treatment Selection Task Team of the Yakima/Klickitat Production Project (unpublished meeting minutes, 1992) developed the following list of potentially essential naturalistic rearing elements:

- reduced rearing densities; .
- incorporation of natural substrate and natural coloration patterns in rearing vessels;
- provision of variable velocities,
- overhead cover and "velocity cover" (boulders) in the rearing vessel;
- visual isolation from humans;
- subsurface feeding and the periodic addition of live food organisms;
- growth rates programmed to match those of the wild donor stock;
- temperature cycles that match those of the donor stream;
- exposure to predators and/or predator avoidance conditioning;
- and extensive pre-release acclimation in a naturalistic vessel supplied by water from the receiving stream.

By contrast, conventional rearing takes place in standard concrete raceways, at standard densities, and without any of the naturalistic features described above.

In summary, naturalistic rearing conditions should be given serious consideration if the survival of the progeny are to have a chance at meaningful contribution to natural production. Naturalistic rearing should receive special consideration when smolt releases are contemplated because the extended rearing period increases opportunities for maladaptive conditioning and suppression of instinctual behavior.

A post-script on this issue is in order. The fact many experiential debilities can be avoided by releasing hatchery-reared fish at an early life stage (fry or small parr) represents a dilemma On the one hand, releases of early presmolt preclude significant “maladaptive conditioning” from hatchery experience and may promote homing fidelity through extended residence in the intended spawning stream. Early releases of presmolts may also counter inadvertent selection in the hatchery and may preclude “latent selection”. On the other hand, post release survival from presmolt releases, especially in infertile streams, is frequently very low or nil (Past et al, 1991; Hume and Parkinson, 1988; Petrosky, 1984), and the opportunities for adverse competitive and predatory impacts on naturally-spawned juveniles are increased substantially.

2.4.3 Artificial Bottlenecks Due to Passage

A particular type of experience which no supplementation planner can afford to ignore is the experience of passing down and back up the hydroelectric system in the Snake and Columbia. Table 3 summarizes adult and juvenile passage survival data for.all of the stream/stock systems with ongoing or proposed supplementation projects in the Columbia Basin (RASP, 1993; survival estimates from System Planning Model database). Attention is directed to the rather startling cumulative adult and juvenile survival rates for many stocks, especially upstream stocks.

The major implication of the survival data summarized above is that density-independent mortality associated with passage through five or more hydro systems will reduce smolt-to-adult survival rates to very low levels. This fact will, in turn, make it virtually impossible for supplementation alone to increase abundance substantially. To see the truth of this assertion, consider a stock production function in which adults are parents and smolts are the recruits. The replacement line for such a curve represents replacement smolt-to-adult survival, and the intersection of the line and the curve defines equilibrium population abundance. The imposition of additional density-independent smolt-to-adult mortality would be reflected in this plot by a counter clockwise rotation of the replacement line (more smolts required per returning adult). Given such a scenario, assume enough supplementation smolts were released to fully seed the habitat. The effect would be nil because natural density-dependent limitation would not permit sufficient smolt production in the subbasin to overcome the density-independent (smolt-to-adult) mortality and fully seed the habitat in the succeeding generation. Therefore, supplementation alone could never restore the complete natural production cycle to historical levels.

Table 3. Summary of adult and juvenile survival rates associated with passage through the mainstem Snake and Columbia for streams with ongoing or planned supplementation projects (data from RASP, 1993).

NOTE: "Adult Survival Index" and "Smolt Survival Index" represent cumulative impacts on the survival of, respectively, adults and juveniles attributable to passage through the subbasin and mainstem Snake and Columbia, The Adult Survival Estimate is computed as the product of estimated cumulative survival past dams, survival through the terminal fishery and pre-spawning survival. The Smolt Survival Index is computed as the product of smolt survival through the subbasin and through the mainstem Snake and Columbia.

STREAM	SPECIES	NUMBER OF DAMS	UPSTREAM DAM SURVIVAL	TERMINAL FISHERY SURVIVAL	PRE SPAWNING SURVIVAL	ADULT SURVIVAL INDEX	SUBBASIN SMOLT SURVIVAL	SMOLT SURVIVAL THROUGH COLUMBIA	SMOLT SURVIVAL INDEX
Imnaha River	Summer Chinook	8	0.53	1.00	0.95	0.51	0.95	0.33	0.31
Upptr Yakima	Spring Chinook	4	0.66	0.86	0.80	0.45	0.53	0.50	0.26
Upper Yakima	Summer Steelhead - A Run	4	0.66	1.00	0.90	0.19	0.51	0.50	0.25
Naches River	Spring Chinook	4	0.66	0.86	0.80	0.45	0.66	0.50	0.33
Toppenish Creek	Summer Steelhead - A Run	4	0.66	1.00	0.90	0.59	0.58	0.50	0.29
Naches River	Summer Steelhead - A Run	4	0.66	1.00	0.90	0.59	0.49	0.50	0.24
Stlmon River, Alturas Lake Creek	Spring Chinook	8	0.53	1.00	0.95	0.51	0.32	0.33	0.11
East Fork Salmon River	Spring Chinook	8	OS3	1.00	0.95	0.11	0.32	0.38	0.12
Upper South Fork Stlmon	Summer Chinook	I	0.53	1.00	0.95	0.51	0.32	0.38	0.12

Table 3, Summary of adult and juvenile survival rates associated with passage through the mainstem Snake and Columbia for streams with ongoing or planned supplementation projects (data from RASP, 1993).

NOTE: "Adult Survival Index" and "Smolt Survival Index" represent cumulative impacts on the survival of, respectively, adults and juveniles attributable to passage through the subbasin and mainstem Snake and Columbia. The Adult Survival Estimate is computed as the product of estimated cumulative survival past dams, survival through the terminal fishery and pre-spawning survival. The Smolt Survival Index is computed as the product of smolt survival through the subbasin and through the mainstem Snake and Columbia.

STREAM	SPECIES	NUMBER OF DAMS	UPSTREAM DAM SURVIVAL	TERMINAL FISHERY SURVIVAL	PRE SPAWNING SURVIVAL	ADULT SURVIVAL INDEX	SUBBASIN SMOLT SURVIVAL	MOLT SURVIVAL THROUGH COLUMBIA	SMOLT SURVIVAL INDEX
West Fork Yankee Forkof Salmon	Spring Chinook	8	0.13	1.00	0.95	0.51	0.32	0.38	0.12
Pahsimeroi River	Summer Chinook	8	0.53	1.00	0.95	0.51	0.32	0.38	0.12
Clear Creek	Spring chinook	8	0.53	1.00	0.95	0.51	0.32	0.33	0.11
Red River	Spring Chinook	8	0.53	1.00	0.95	0.51	0.32	0.33	0.11
American River	Spring Chinook	8	0.53	1.00	0.95	0.51	0.32	0.33	0.11
Crooked River	Spring Chinook	8	0.53	1.00	0.95	0.51	0.32	0.33	0.11
Papoose Cmk	Spring Chinook	8	0.53	1.00	0.95	0.51	0.32	0.33	0.11
Pete King Creek	Spring Chinook	8	0.53	1.00	0.95	0.51	0.32	0.33	0.11
Squaw Creek	Spring Chinook	8	0.53	1.00	0.95	0.11	0.32	033	0.11
White Sand Creek	Spring Chinook	8	0.53	1.00	0.95	0.11	0.32	0.33	0.11

Table 3. Summary of adult and juvenile survival rates associated with passage through the **mainstem** Snake **and** Columbia for streams with ongoing or planned supplementation projects (data from RASP, 1993).

NOTE: “Adult Survival Index” and "**Smolt** Survival Index” represeat cumulative impacts on the survival of, respectively, adults and juveniles attributable to passage through the **subbasin** and **mainstem** Snake and Columbia, The Adult Survival Estimate is computed as the product of estimated cumulative survival past **dams,** survival **through** the terminal fishery and **pre-spawning survival. The Smolt** Survival Index is computed as the product of **smolt** survival through the **subbasin and through the mainstem** Snake and ‘Columbia,

STREAM	SPECIES	NUMBER OF DAMS	UPSTREAM DAM SURVIVAL	TERMINAL FISHERY SURVIVAL	PRE SPAWNING SURVIVAL	ADULT SURVIVAL INDEX	SUBBASIN SMOLT SURVIVAL	SMOLT SURVIVAL THROUGH COLUMBIA	SMOLT SURVIVAL INDEX
Big Flat Creek	Spring Chinook	8	0.53	1.00	0.95	0.51	0.32	0.33	0.11
Crooked Fork Creek	Spring Chinook	a	0.53	1.00	0.95	0.51	0.41	0.33	0.14
Lemhi River	Spring Chinook	a	0.53	1.00	0.95	0.11	0.41	0.33	0.14
Hood River	Winter Steelhead	I	0.90	0.70	0.99	0.62	0.91	0.86	0.71
Hood River	Spring Chinook	1	0.90	0.92	1.00	0.83	1.00	0.86	0.16
Hood River	Summer Steelhead - A Run	1	0.90	0.70	1.00	0.63	0.98	0.86	0.14
Umatilla River	Summer Steelhead - A Run	3	0.73	0.75	0.80	0.44	0.76	0.60	0.45
Umatilla River	Spring Chinook	3	0.73	1.00	0.50	0.36	0.79	0.60	0.47
Umatilla River	Fall Chinook	3	0.73	1.00	0.10	0.36	0.50	0.40	0.20
Catherine Creek	Spring Chinook	8	0.53	0.95	0.85	0.43	0.83	0.33	0.27

Table 3. Summary of adult and juvenile survival rates associated with passage through he mainstem Snake and Columbia for streams with ongoing or planned supplementation projects (data from RASP, 1993).

NOTE: "Adult Survival Index" and "Smolt Survival Index" represent cumulative impacts on the survival of, respectively, adults and juveniles attributable to passage through the subbasin and mainstem Snake and Columbia, The Adult Survival Estimate is computed as the product of estimated cumulative survival past dams, survival through the terminal fishery and pre-spawning survival. The Smolt Survival Index is computed as the product of smolt survival through the subbasin and through the mainstem Snake and Columbia,

STREAM	SPECIES	NUMBER OF DAMS	UPSTREAM DAM SURVIVAL	TERMINAL FISHERY SURVIVAL.	PRE SPAWNING SURVIVAL	ADULT SURVIVAL INDEX	SUBBASIN SMOLT SURVIVAL	SMOLT SURVIVAL THROUGH COLUMBIA	SMOLT SURVIVAL INDEX
Lookinglass River	Spring Chiwok	8	0.53	0.91	0.85	0.43	0.83	0.33	0.27
Lostine River	Spring Chinook	8	0.13	0.95	0.85	0.43	0.83	0.33	0.27
Little Sheep Creek	Summer Steelhead - A Run	8	0.53	1.00	0.95	0.51	0.95	0.33	0.31
Catherine Creek	Summer Steelhead - A Run	8	0.53	0.95	0.90	0.46	0.83	0.33	0.28
Deer Creek	Summer Steelhead - A Run	8	0.53	0.95	0.90	0.46	0.83	0.33	0.28
Fly Creek	Summer Steelhead - A Run	8	OS3	0.95	0.90	0.46	0.83	0.33	0.28
Indian Creek	Summer Steelhead - A Run	8	0.53	0.95	0.90	0.46	0.83	0.33	0.28
Klickitat River	Spring Chinook	1	0.90	0.63	0.50	0.28	1.00	0.86	0.86
Klickitat River	Summer Steelhead - A Run	I	0.90	0.46	0.90	0.37	1.00	0.86	0.86

Table 3, Summary of adult and juvenile survival rates associated with passage through the **mainstem** Snake and Columbia for streams with ongoing or planned supplementation projects (data from RASP, **1993).**

NOTE: "Adult Survival Index" and "**Smolt** Survival Index" represent cumulative impacts on the survival of, respectively, adults **and** juveniles attributable to passage through the subbasia and **mainstem Snake** and Columbia, The Adult Survival Estimate is computed as the product of estimated cumulative survival past dams, survival through the terminal **fishery** and **pre-spawning survival. The Smolt** Survival Index is computed as the product of **smolt** survival through the subbasio and through the **mainstem** Snake and Columbia,

STREAM	SPECIES	NUMBER OF DAMS	UPSTREAM DAM SURVIVAL	TERMINAL FISHERY SURVIVAL	PRE SPAWNING SURVIVAL	ADULT SURVIVAL INDEX	SUBBASIN SMOLT SURVIVAL	SMOLT SURVIVAL THROUGH COLUMBIA	SMOLT SURVIVAL INDEX
Chiwawa Rivcc	Spring Chinook	7	0.46	1.00	0.70	0.32	0.92	0.25	0.23
Wenatchee Rivet	Summer Chinook	7	0.46	1.00	0.70	0.32	0.80	0.39	0.31
Methow River	Summer Chinook	9	0.41	1.00	0.90	0.37	0.85	0.21	0.24
Okanogan River	Summer Chinook	9	0.41	1.00	0.90	0.37	0.90	0.28	0.26
Twisp River	Spring Chinook	9	0.41	1.00	0.90	0.37	0.90	0.18	0.17
Chewuck River	Spring Chinook	9	0.41	1.00	0.90	0.37	0.90	0.18	0.17
Methow Rivcc	Spring Chinook	9	0.41	1.00	0.90	0.37	0.90	0.18	0.17
Tucannon River	Spring Chinook	8	0.53	1.00	0.60	0.32	1.00	0.34	0.34
Lower Yakima	Fall Chinook	4	0.66	1.00	0.90	0.59	0.69	0.38	0.17
upper Yakima	Fall Chinook	4	0.66	1.00	0.90	0.59	0.34	0.38	0.13
Naches Rivet	Coho	4	0.66	1.00	0.90	0.59	0.66	0.44	0.29

Table 3. Summary of adult and juvenile survival rates associated with passage through the mainstem Snake and Columbia for streams with ongoing or planned supplementation projects (data from RASP, 1993).

NOTE: "Adult Survival Index" and "Smolt Survival Index" represent cumulative impacts on the survival of, respectively, adults and juveniles attributable to passage through the subbasin and mainstem Snake and Columbia, The Adult Survival Estimate is computed as the product of estimated cumulative survival past dams, survival through the terminal fishery and pre-spawning survival. The Smolt Survival Index is computed as the product of smolt survival through the subbasin and through the mainstem Snake and Columbia,

STREAM	SPECIES	NUMBER OF DAMS	UPSTREAM DAM SURVIVAL	TERMINAL FISHERY SURVIVAL.	PRE SPAWNING SURVIVAL	ADULT SURVIVAL INDEX	SUBBASIN SMOLT SURVIVAL	SMOLT SURVIVAL THROUGH COLUMBIA	SMOLT SURVIVAL INDEX
Lower Yakima	Coho	4	0.66	1.00	0.90	0.59	0.66	0.44	0.29
Naches Rivcc	Summer Chinook	4	0.66	1.00	0.80	0.52	0.31	0.68	0.21
Slate Creek	Spring Chinook	8	0.49	1.00	0.90	0.44	0.50	0.21	0.13
Meadow Creek	Summer Chinook	8	0.49	1.00	0.90	0.44	0.10	0.21	0.13
Meadow Creek	Spring Chimok	8	0.49	1.00	0.94	0.44	0.50	0.25	0.13
Meadow/SF Clearwater	Spring Chinook	8	0.49	1.00	0.90	0.44	0.10	0.25	0.13
Newsome Creek/S.F. Clearwater	Spring Chinook	8	0.49	1.00	0.90	0.44	0.50	0.25	0.13
Mill Creek	Spring Chinook	8	0.49	1.00	0.90	0.44	0.50	0.25	0.13
S.F.Clearwater River	Fall Chinook	8	0.49	1.00	0.90	0.44	0.10 '	0.33	0.17
Selway River At USFS Fenn Ranger Station	Fall Chinook	8	0.49	1.00	0.90	0.44	0.50	0.33	0.17

Table 3, Summary of adult and juvenile survival rates associated with passage through the mainstem Snake and Columbia for streams with ongoing or planned supplementation projects (data from RASP, 1993).

NOTE: "Adult Survival Index" and "Smolt Survival Index" represent cumulative impacts on the survival of, respectively, adults and juveniles attributable to passage through the subbasin and mainstem Snake and Columbia. The Adult Survival Estimate is computed as the product of estimated cumulative survival past dams, survival through the terminal fishery and pre-spawning survival. The Smolt Survival Index is computed as the product of smolt survival through the subbasin and through the mainstem Snake and Columbia,

STREAM	SPECIES	NUMBER OF DAMS	UPSTREAM DAM SURVIVAL	TERMINAL FISHERY SURVIVAL	PRE SPAWNING SURVIVAL	ADULT SURVIVAL INDEX	SUBBASIN SMOLT SURVIVAL	SMOLT SURVIVAL THROUGH COLUMBIA	SMOLT SURVIVAL INDEX
Lapwai Creek At Confluence With Clearwater River	Fall Chinook	8	0.49	1.00	0.90	0.44	0.50	0.33	0.17
Slate Creek	Spring Chinook	8	0.49	1.00	0.90	0.44	0.50	0.21	0.13
Lolo Cnek	Spring Chinook	8	0.49	1.00	0.90	0.44	0.50	0.25	0.13
Lolo Creek Al Confluence With Clearwater Rivet	Fall Chinook	8	0.49	1.00	0.90	0.44	0.50	0.33	0.17

3. GUIDELINES FOR PLANNING PROPAGATION PROJECTS

3.1 USE OF THE GUIDELINES

The planning guidelines presented here are **not** rules to be followed in every detail. Their purpose. is to guide the development of supplementation plans through a focus on the life history -- habitat relationships of the population to be restored. All the detailed information called for in the guidelines does not need to be in hand before the recovery plan is implemented. In some cases, information on life histories and habitat will be sparse, in other cases it will be extensive. Where recovery using artificial propagation is implemented without all the requisite information, these planning guidelines become iterative. Once the plan is implemented, monitoring and evaluation will begin to generate the missing information which leads to an iterative update of the plan. Figure 3, which will be discussed in detail in Section 3.4.2 illustrates the cyclic nature of the proposed planning process.

3.2 APPROACH

A basic premise of this report is that adequate design of artificial propagation to support recovery must be based on a complete review of the life history-habitat relationships of the ESU. The general Iife history habitat sequence for Columbia River salmon consists of fourteen cells (Figure 4) and those cells comprise a basic framework for diagnosing limiting factors, identifying critical habitat, selecting culture practices, assessing risk and designing monitoring programs. The analysis of each cell is comprised of a detailed evaluation of ***existing*** information on habitat, population dynamics and demographics (Table 4).

3 3 DETERMINING THE NEED FOR ARTIFICIAL PROPAGATION

Our review of USFWS (1990) and Hard et al. (1992) leads us to this conclusion regarding the use of artificial propagation in the recovery of listed species of Pacific salmon: The use of artificial propagation is a last resort which can be employed only after it is determined that other remedies to correct problems with the ESU's critical habitat cannot be implemented or become effective soon enough to prevent extinction. The use of artificial propagation is a temporary recovery measure and it must be planned and implemented in a way that does not alter the ESU's genetic structure or interfere with the recovery of the population in its natural habitat. To be consistent with those conclusions, especially the first, a recovery plan that includes artificial propagation should document the procedure used to reach the conclusion that a hatchery was necessary. A proposed procedure comprised of 4 steps is presented in 3.3.1 – 3.3.4

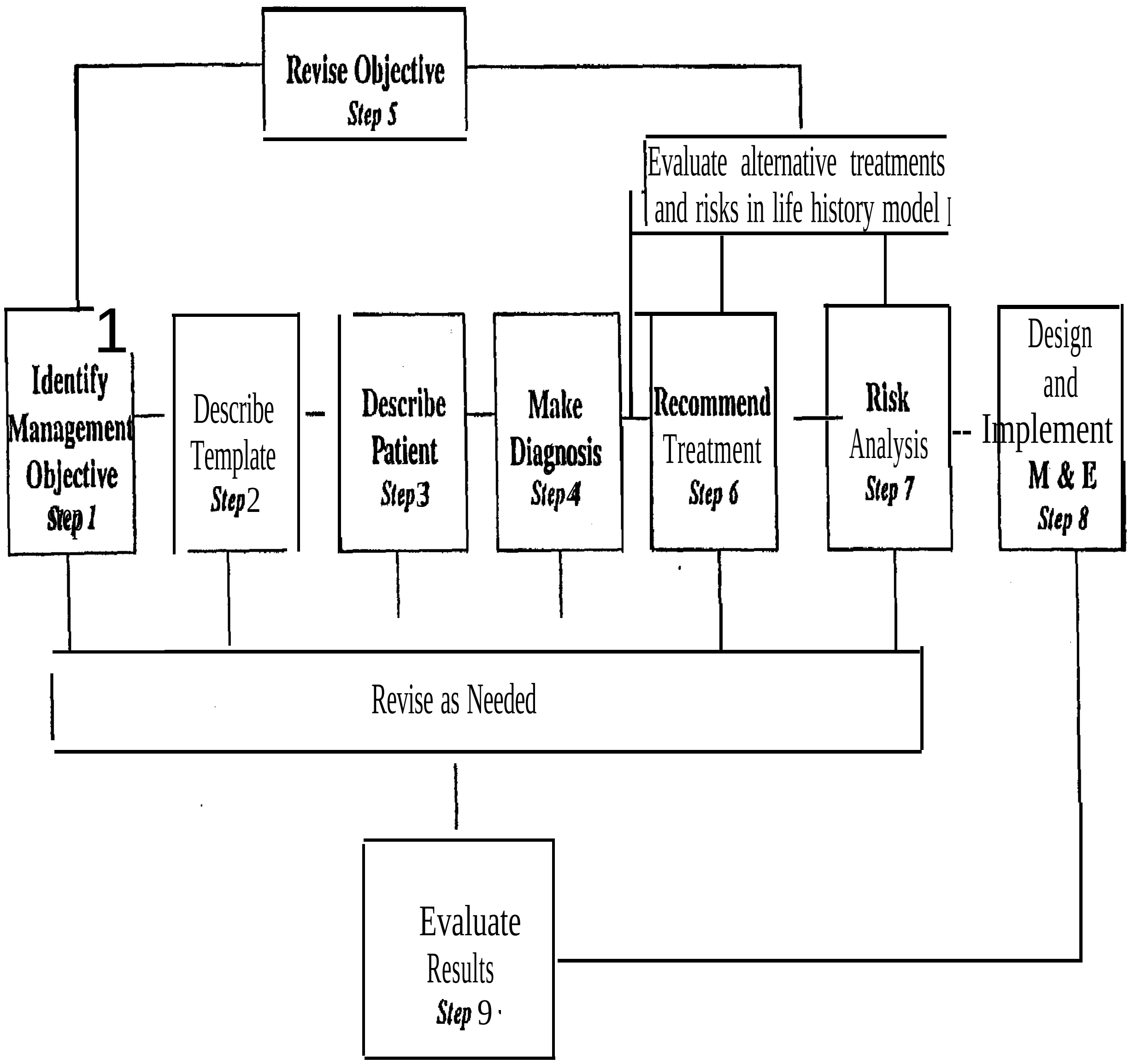

Figure 3, A sequence of planning steps for supplementation projects,

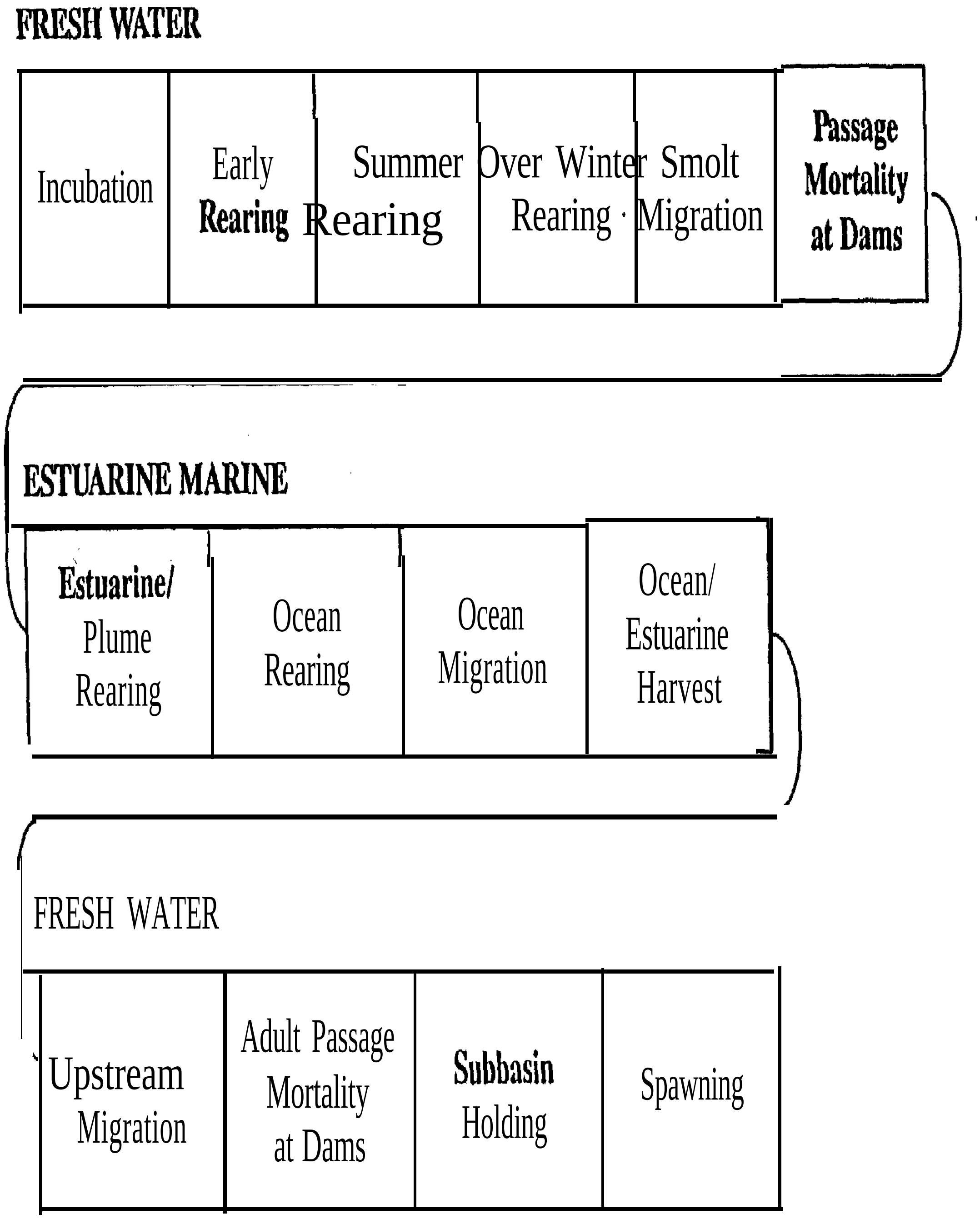

Figure **4.** Sequence of Habitat and Life **History** Stages for Pacific Salmon,

Table 4. Information reviewed in each of the fourteen life history cells (Figure 4). The example given here is for the egg incubation cell.

Habitat	Population Dynamics	Demographics
Distribution of spawning habitat in subbasin Quality and quantity of habitat	Mortality Interaction-competition and predation	Timing of spawning Life histories Timing of emergence Spawning distribution

33.1 Identifv Specific Factors Limiting Recovery or Causing Continued Depletion of Listed Suecies

An early step in the process of selecting recovery methods is the identification of the factors causing the species to be listed. There may be a single severe problem at a specific life stage or a cumulative series of problems acting during different life stages or both. The patient-template analysis described in Sections 3.4.1.1 to 3.4.1.3 is one approach that can be used to identify limiting factors as well as provide information needed to design an artificial propagation program if it is deemed necessary.

3.3.2 Identifv the Management Actions Required to Reduce the Impact of the Limiting; Factors and Bring about the *Natural* Recovery of the Suecies

Once the limiting factors have been identified, management actions that create the limitation and appropriate corrective actions should be identified. Mortality of juveniles passing dams might require management actions such as drawdown during migration, screening, or transport; excessive harvest would require reduced catch or a change in the fishery, i.e., more terminal and less mixed stock harvest, excessive siltation in spawning and rearing areas would require revised logging or grazing practices and selected habitat restoration.

3.3.3 Estimate the Time Needed for *Natural* Recovery Once Management Actions are Imdemented or the Process Leading to Imdementation is Started. Estimate the Probability that the Suecies will go Extinct Before the Management Actions can Bring About Recovery

In many cases, management actions to correct a limiting factor will not result in rapid recovery but a gradual rebuilding of the population. In other cases management actions might require expensive construction or manipulation of resources that require time to plan before implementation. The time required for recovery should be determined as well as the likelihood that the stock will go extinct before the management action can be implemented or become effective.

3.3.4 <u>If it is Detenuined that there is a Low Probability that the Species will go Extinct Before the Management 'Actions Identified in 3.3.2 can Bring About Natural Recovery, then Design Appropriate M&E and Proceed with Implementation. However, if Reliance Only on Management Actions for Natural Recovery Results in a High Probability of Extinction, then Appropriate Artificial Propagation Strategies Should be Designed to a) Prevent Extinction and b) Assist in Recovery While Other Management Activities Attempt to Restore the Ecosystem</u>

Artificial propagation of the listed species should be considered as an appropriate recovery tool if natural recovery following removal of limiting factors will take too long and there is a likelihood that the population will go extinct before natural recovery processes can become effective. The rest of this report assumes that these steps have been taken and it has been determined that artificial propagation is required for the recovery of the listed species. Artificial propagation may be employed in other less critical situations where it will accelerate recovery without genetic risk to the ESU (see Section 1.1).

3.4 GUIDELINES FOR INCORPORATING ARTIFICIAL PROPAGATION INTO RECOVERY PLANS

3.4.1 <u>Background</u>

As-shown in Section 1.1, the ESA specifies that its goal is the conservation of ecosystems upon which the endangered species depend. That goal requires that the recovery plan focus on the restoration of ecological relationships as well as the numerical size of the ESU. While restoration of fish numbers is important, a sustainable increase in population size, requires the restoration of important ecological relationships. Successful ecological restoration is the acid. test of our understanding of how the elements of an ecosystem function (Bradshaw 1990). Restoration, measured as an increase in natural production and accomplished through the use of supplementation,[3] is a test of our understanding of the relationships among the life history of the target stock, its habitat, and artificial propagation. This understanding is developed and demonstrated through the completion of steps 2 - 6 in the planning process described in detail in 3.4.2.

---

[3] Although we refer specifically to supplementation here the discussion also applies to conventional hatchery practices that might have to be employed in cases where extinction is eminent. When conventional hatchery practices are employed, they should be considered short-term evolving into supplementation and finally termination when the natural productivity of the ESU's ecosystem has sufficiently improved.

When using supplementation to recover an ESU, its important to avoid the traditional approach of focusing exclusively on production numbers — hatchery sizing, feed programming, release targets, and escapement goals. The guidelines described here ask the recovery team contemplating the use of supplementation to first look back in time at the stream/stock system before degradation occurred and then-to describe how the original system functioned. This is an essential step because it focuses attention on ecological relationships early in the planning process.

Stocks, as defined by Bicker (1972), are the basic management units upon which the conservation of the species depends (Rich 1938). It is the diversity contained within and between stocks that must be conserved if the fisheries are to be sustained in the face of natural and man-made changes in the environment. When defining the boundaries around stocks the manager must take into account the tradeoff between the risk of a loss of diversity within and between stocks — the Types 2 and 3 genetic risks of Busack (1990). Drawing a wide geographic circle around a stock could precipitate management activities that reduces between-stock diversity if the circle inadvertently included more than one distinct stock. Conversely, a small circle might exclude a legitimate part of a stock and contribute to loss of within-stock diversity.

The planning guidelines described below presuppose that the physical boundary of the ESU has been defined and its genetic characterization completed. The ESU designation (broad or narrow) effects treatment options, risk assessment and risk management in a supplementation project. For example, a narrow stock designation controls risk by restricting treatment strategies. A broader stock designation allows greater management flexibility, but it requires extensive monitoring and evaluation to control risks. In addition, a single ESU might be comprised of distinct breeding units which should not be combined or mixed in artificial propagation programs.

3.4.2 <u>Planning Steps</u>

The planning guidelines are comprised of 9 Steps (Figure 3) which are described within the context of a clinical model. In the first Step, goals are established, Steps 2 to '4 are fact-finding and descriptive; Steps 6 and 7 involve analysis of risks and benefits, and Steps 8 and 9 are monitoring and evaluation. We use clinical terminology to describe the 9 planning Steps. For example, the degraded ecosystem and population is the patient and a correct diagnosis is critical to the selection of an appropriate treatment. The 9 Steps are:

1. **Identify Management Objectives.** The objective describes the desired future condition of the stream/stock system (expected benefits).

2. **Describe Template.** The template describes the healthy stream/stock system.

3. **Describe Patient** The patient describes the current condition of the stream/stock system.

4. **Make Diagnosis.** The diagnosis identifies limiting factors that prevent the patient from reaching the objective.

5. Revise **Objective. At** this point the original objective should be reviewed and revised if appropriate.

6. **Recommend Treatment** The treatment describes the artificial propagation strategies expected to achieve the objective.

7. **Risk Analysis.** Risk analysis is based on the uncertainties associated with the recommended treatments.

8. **Design aud Implement Monitoring and Evaluation.** Risk is "managed" through monitoring and research.

9. **Evaluate Results. M &** E results are evaluated following implementation and the plan is revised consistent with the new information.

3.4.2.1 Identify Recovery Objectives Related to Propagation (Step 1)

Traditionally the goals of restoration programs focused on numerical targets (spawning escapements, harvest targets, pounds released from the hatchery, etc.). However, if the restoration of degraded ecosystems and with it listed populations is to be successful, the numerical production targets must include targets that specify the quality of the population to be restored (Reiger and Baskerville 1986). When artificial propagation is employed, we recommend recovery objectives include four quality standards: Post release survival, reproductive success, long-term fitness and ecological interactions.

Post-Release Survival

Post-release survival is measured from the time of release to the time adults return to the subbasin or are harvested in a fishery. The system planning model discounts the contribution of hatchery fish by 50% to account for differential survival between wild and hatchery smolts (Monitoring and Evaluation Group 1989). Given the magnitude of the discount applied to hatchery fish, improving post-release performance can make a large contribution to the success of a recovery program. To improve post-release survival, evaluation projects should focus on learned behavior in the hatchery, physiological state of the hatchery fish, ecological factors such as predation and competition, and environmental factors such as flow and temperature patterns.

Reproductive Success

Reproductive success measures how well artificially propagated fish reproduce in the natural environment. It is limited to those changes in the natural reproductive process induced by the hatchery experience that do not persist into the next generation. Reproductive success is broadly defined as the number of offspring produced per spawner and it is influenced by:

- changes in average fecundity of the stock

- pre-spawning mortality

- large- and small-scale spawning distribution (homing to appropriate drainage or selection of quality spawning bed)

- spawning effectiveness (mate acquisition, redd digging capability, spawning timing, and egg retention)

- survival of progeny of hatchery-reared fish across significant life history stages (egg-to-fry, fry-to-presmolt, and presmolt-to-smelt survival and recruit per spawner ratios).

Long-Term Performance

Long-term performance is defined as the capacity of a population to persist in the face of environmental variability while undergoing natural genetic change. Ultimately, long-term performance is demonstrated by the simple fact that a population has maintained its productivity over a long period of time. Long-term performance of a stock might be indexed by changes in the ratio of recruits to spawners, overall egg to adult survival and survival between life history stages, gene frequencies as measured by electrophoresis, by changes in life history patterns. Long-term performance is a relatively new approach to the evaluation of artificial propagation, hence new tools and methodologies are needed. Standards designed to measure long-term performance must consider the four genetic risks associated with supplementation: Extinction, loss of within-population variability, loss of between-population variability and domestication (Busack 1990).

Ecological Interactions

Hatchery fish released into the natural stream immediately become a part of the ecological matrix comprised of the physical habitat and its biota, including predators and competitors. Hatchery-reared fish both affect and are affected by the ecological matrix of the stream. For example, one of the most controversial biotic effects is the impact of a successful supplementation program on non-target species or races. The inter- and intra-specific trade-offs implicit in any supplementation program and the performance standards used to measure those trade-offs must be made explicit. Performance standards designed to measure the interaction between ecological factors and supplementation may be derived from:

- factors limiting production, including identification of critical or unique seasonal patterns of habitat used by specific life history stages

- species-specific carrying capacities in mainstem reaches and tributaries;

- changes in critical habitat parameters (e.g., adult passage at dams and other obstructions) effectiveness of screening and bypass systems for irrigation diversions; adequate in-stream flows for spawning, rearing, and outmigration; and water quality, especially as impacted by such human activities as logging and grazing

- competitive and genetic interactions between resident @e-existing) and anadromous trout (supplemented)

- interactions between pre-existing resident trout and other anadromous species

- interactions among supplemented and natural anadromous salmonids themselves (e.g., competition, predation, “pied piper” effects, and residualism)

- specific times and places associated with large losses of outplanted fish and development of compensatory release strategies

Every major subbasin in the Columbia River has at least generalized objectives contained in statewide management plans (for example, see Oregon’s Species Management Plans and Idaho’s Anadromous Fishery Management Plan). In addition, management objectives for specific subbasins are found in subbasin planning documents, hatchery master plans, and in individual regional, district or tribal planning documents. Management objectives might be inferred from harvest regulations, stocking programs, and agency comments on forest practice applications, environmental impact statements, and proposed water quality and land use regulations. Since the management objectives and programs for nonlisted species might conflict with listed ESU's, these sources should be consulted when setting recovery objectives.

3.4.2.2 Describe the Template and Patient (Steps 2 and 3)

The template describes the historical performance of the stream/stock system. Its a pattern against which the present condition (patient) and proposed future condition (objective) are compared to identify limiting factors and reasonable expectations for increased natural production. The template analysis makes use of historical and contemporary information specific to the stream/stock targeted for recovery, and, when necessary, it uses inferences drawn from the literature on stocks outside the target subbasin. The template should not be confused with the objective. The template describes the historical performance of the stream/stock system and the objective describes that part of the template recovery activities will attempt to restore. The patient is the stream/stock system as it exists today and described in the same terms as the template.

The analysis of patient and template addresses three elements important to the life history-habitat relationship of the ESU: geography, time, and biology. The salmon’s life history involves important biological functions such as spawning, migration, feeding, and escaping predators which are carried out in a series of geographically and seasonally connected places (Thompson 1959). The patient-template analysis is a comparative assessment of the information called for in Figure 4 and Table 4. Appendix A contains a set of forms to assist in organizing and identifying information needed to complete a patient-template analysis for the freshwater life history stages.

3.4.2.3 Diagnosis (Step 4)

The diagnosis is essentially a comparison cell by ceil (Figure 4, Table *4,* and Appendix A) of the template and patient information. The purpose of the diagnosis is to identify the factors limiting natural production, select the appropriate management activity to correct or circumvent the limitation, and describe the life history-habitat relationships that the recovery plan should attempt to rebuild or repair.

Table 5 was prepared to serve as a guide to completing the diagnosis. The questions in Table 5 are divided into three categories: those questions that describe the stream ecosystem and its capacity, questions that describe the performance (production) of the target population, and questions that describe the limiting factors. Answers to the questions in Table 5 lead to one of the four conclusions listed at the bottom of the table. The four conclusions are described below:

A recognition that there is not enough life history - habitat information to adequately describe the patient. Identification of the appropriate recovery actions requires a minimal understanding of the life history – habitat relationship in the ESU. This is especially true where the integration of natural and hatchery production (supplementation) is being proposed. The development and implementation of recovery plans often cannot be delayed while complete life history-habitat information is collected. When there is incomplete information and implementation of artificial propagation must proceed with a high level of uncertainty the plan must include extensive M & E to control the risks.

A recognition that the ESU is at its natural production capacity. A comparison of the template and patient might reveal that the performance of the stream/stock cannot be increased through supplementation, i.e., the degraded freshwater habitat is fully seeded, albeit at a reduced level from the historic. In that case, any increase in total production would have to'come from a well-planned conventional hatchery — a conventional hatchery that added to and did not replace natural production. Such a program must be designed to minimize risk to the natural production system and the genetic structure of the ESU.

A recognition that the existing recovery objective needs revision. (C) The patient-template analysis might show that the management expectations for the ESU are not consistent with its potential. Assuming the recovery team has confidence in the analysis, the objective should be changed and the diagnosis repeated.

A recommendation to implement specific management activities to circumvent or correct the limitation in natural production. (D) The diagnosis might lead to the conclusion that natural production can be increased through artificial propagation in combination with other management activities which might include habitat improvement, water management, removal of barriers, harvest regulation, or some combination of the above. The team must explain how the factors limiting production will be corrected by the chosen set management activities.

Table 5. Diagnosis of Patient Template Information.

CAPACITY/ECOSYSTEM DESCRIPTION

1) Can the template/patient be described with sufficient detail to identify the factor(s) preventing the patient from achieving the objective? If yes, continue, If no see Conclusion **A.**

2) Does the template/patient comparison suggest that current natural production is less than historic? If no, see Conclusion **B.** If yes, continue,

31 **a.** Are the historic life history patterns present in the patient population?

b. Has the quality and quantity of **abiotic** and biotic habitat been altered?

c. Is the difference between template and patient due to fishery management activities?

d. Is the difference between template and patient due to factors outside the **subbasin** such as passage?

4) Describe the specific factors in **(3a-3d)** that contribute to the difference between template and patient, Assess the relative effect of each factor on capacity, **Proceed** to the next set of questions,

PERFORMANCE OF THE TARGET POPULATION

5) a) Is the habitat fully seeded at each life history stage?

b) Are density, growth, survival, by life stage in the patient comparable to other populations reported in the literature?

c) Has the distribution of the target population within the **subbasin** been reduced?

d) Can the adult stock production function be described?

e) Are density independent or density dependent factors controlling population size at each life stage?

6) Does **5a-e** suggest potential to increase natural production? If no, see conclusion **B.** If yes, continue,

7) Does the answersto **5a-e** generally support the target population size contained in the objective? If no, see Conclusion **C.** If yes, continue to next **page.**

POPULATION LIMITING FACTORS

8) a, Has the timing of life history events changed putting them out of synch with flow and temperature patterns?

b: Have flow and temperature changed in a way that is detrimental to the completion of template life history patterns?

c. Are there biotic interactions limiting production of the target population?

d. Are there full or partial migration blocks (juvenile and adult) that were not present in the template?

e. Can specific mortality factors be identified such as fine sediment in spawning gravels or improperly screened diversions?

f. Would the planting of hatchery fish create a bottleneck at a later life history stage/habitat?

g. Have fecundity, sex ratio, or reproductive success changed7

h. Are there genetic changes that might account for the differences in template and patient,

91 Are the limiting factors correctable? If yes, see Conclusion **D.** If no, see Conclusion **C.**

CONCLUSIONS

A) A recognition that there is not enough life history-habitat information to adequately describe the patient,

B) A recognition that the ESU is at its natural production capacity.

C) A recognition that the existing recovery objective needs revision,

[illegible] specific management activities to circumvent or correct the limitation in natural production.

3.4.2.4 Revise the Objective (Step 5)

At this point in the development of the propagation element of the recovery plan, the team should revisit the original recovery objective to determine if it is consistent with the patient-template analysis. The objective should describe what part of the template (historic ESU) production can be reasonably obtained through artificial propagation.

3.4.2.5 Recommend Treatment (Step 6)

To reach this step, the diagnosis should have indicated that propagation alone or in combination with another management action such as habitat restoration is a candidate strategy to restore or increase natural production in the ESU. In this step of the planning process, the manager develops and evaluates alternative propagation strategies.

General Guidelines for Treatment Selection

Kapuscinski et al. (1991) and Chapter C of the ISP (CBFWA 1991) discuss the selection of propagation strategies in general, and Hard et al. (1992) discusses the use of propagation with specific emphasis on the ESA. Reisenbichler and McIntyre (1986) give guidelines for integrating natural and artificial production of salmonids. Those reports offer important guidance for development of alternative treatment strategies. The following discussion will draw heavily on the advice they contain.

Supplementation strategies are comprised of six basic elements: broodstock selection, broodstock collection and mating protocols, escapement management, incubation and rearing practices, release variables, and project scale. In the discussion that follows, we present alternative approaches to each of these basic elements and, in some cases, recommend priorities for the alternative treatments. This discussion of alternative treatments provides an introduction to the subject. The documents cited above should be consulted for more details.

Broodstock Selection Genetic diversity is organized hierarchically (Currens et al. 1991). As a part of the hierarchy, the ESU may be comprised of smaller, less inclusive breeding groups that persist and maintain their evolutionary independence. To maintain interpopulation diversity in such an ESU the cross breeding of those smaller units should be avoided (Hard et al. (1992). The degree of separation in the smaller breeding units depends on balancing the potential problems of inbreeding and outbreeding (Hard et al. 1992). To insure long-term fitness in an artificially propagated ESU, brood fish should be selected from breeding groups that are similar in genetic resources, life history, and originating environments (ecological similarity) (Kapuscinski et al. 1991). Each of the three similarity factors is discussed below:

Genetic Similarity. Analysis of the genetic structure of the donor and target population should be completed to determine if the stocks are phylogenetically similar. The manager should consult with a geneticist to obtain help in determining genetic similarity. Distance from the target stream may be used as a surrogate for genetic similarity if'the habitats in the donor and target stream are similar. However, even streams that are close may support genetically different stocks. For example, Wade (1986) reported reduced resistance to the parasite ***Ceratomyxa shasta*** in the native stock in the Nehalem River, Oregon. He attributed the change in resistance to the planting of nonresistant fish from the nearby Trask stock. It's important to avoid mixing ancestrally divergent populations even if they are in close proximity (Kapuscinski **et** al. 1991).

Life Hiiorv **Similarity.** Comparable life history patterns between the donor and patient stock might reflect genetic similarity and also afford the best opportunity for the donor stock to adapt to the habitat and environmental conditions in the target stream. Life history traits such as size and time that juvenile migrants leave the subbasin, the timing of migration through the **mainstem** and ocean entrance, age structure of the spawning population, time of spawning, distance from estuary to the spawning grounds, are some of the life history traits that should be evaluated for similarity between the donor and recipient stock.

Ecological Similarity. Ecological similarity can be evaluated through a patient-template analysis. In this case, the patient is the donor **stock** described in the context of its native stream and habitat compared to the target stream. Human alteration of the donor and target habitats must be taken into account.

Broodstock Collection and Mating Protocols When selecting brood from an ESU the number of brood fish removed should not create genetic risks for the donor stock (**Busack** 1990 and Ryman and **Laikre** 1991). To avoid those risks, artificial propagation in the recovery plan must be appropriately scaled (Hard et al. 1992). When setting the scale of artificial propagation the manager must take into consideration the carrying capacity of the stream, the release methods (timing and density), and the existing size of the natural population (Hard et al. 1992). In addition, when selecting mating strategies the manager needs to consider life history and effective population size.

Life **History.** All of the donor stock's life histories should be represented in the fish bred in the hatchery. To achieve this goal the broodstock should reflect the following characteristics in the natural population: age structure, time of spawning, spawning location, migration timing and, where possible, juvenile smolt migration.

Effective Population Size. The effective population size (see Section 1.3 for definition of effective population size) of the fish bred in the hatchery should be maximized (Kapuscinski et al. 1991 and Hard et al. 1992). There is no single minimum effective population size (Kapuscinski et al. **1991),** however, Lande and **Barrowclough** (1987) suggest several hundred per generation. This number of spawners may be impossible to collect from the natural spawning population. In those situations, mating protocols should be employed that reduce the variance in the contribution of parents to the next breeding generation (Hard et al. 1992). Kapuscinski et al. (1991) give designs for three mating protocols: single male and single female, factorial cross and Dialel cross. See Section 2.5 for a detailed discussion of effective population size.

Escapement Management

Once artificial propagation of a listed ESU is underway, the manager must decide how the broodstock will be selected from the mix of wild and hatchery fish returning to the target stream. As a general rule, the broodstock should not include returning hatchery fish (Hard et al. 1992). Where this rule is impossible to implement and returning hatchery fish must be incorporated into the brood stock, care must be taken to ensure the repeated propagation of hatchery fish does not result in genetic or life history changes from the naturally spawning ESU. When hatchery fish are incorporated into the broodstock, extensive monitoring of the hatchery and wild populations must be built into the recovery plan.

Incubation and Rearing Practices

Post-release survival may be heavily influenced by the rearing methodologies and physical habitat of the hatchery. Survival is dependent on fish health, and in general, the hatchery manager has to be concerned about two kinds of health:

> clinical health in the hatchery which is threatened by disease, poor nutrition that leads to physiological anomalies, and stress from crowding or chemical quality of the water
>
> ecological health which is threatened by the lack of exposure to predators, inability to compete for food and space in the wild, and release to the stream at sixes, times and places that differ from the normal life history patterns of the stock

The first concern has received a lot of attention and there are generally accepted procedures to ensure clinical health of a hatchery population. To maintain ecological health, the manager should attempt, to the extent possible, to incubate and rear the juveniles in ways that reflect natural conditions. Ideally the simulation of natural conditions during hatchery rearing should reduce random mortality while duplicating the natural selective mortality (Bowles and Leitzinger 199 1). Natural rearing techniques are still experimental, however, recent research in this area should lead to the development of effective rearing practices. For the present, the manager should consult Kapuscinski et al. (1991), Steward and Bjomn (1990), Meffe (1986), Allendorf and Ryman (1987), and Nelson and Soule (1987) for more information and specific suggestions.

The artificial propagation of listed ESU's requires additional safeguards against facility failure especially where the populations are small. The risk of facilities failure should be reduced by the distribution of fish and/or eggs among two or more hatcheries.

Release Variables

The time, size, and place of release of hatchery-reared fish can have important effects on life history, post-release survival and the genetic structure of the stock. The first priority should be to mimic natural life history. Even in conventional hatchery programs, practices that mimic natural life history have a better chance of achieving project objectives (Reimers 1979), particularly in areas with existing natural production. Sixes, times and places of release consistent with natural life history can be inferred from the patient-template analysis.

Proiect Scale

The number of propagated fish released into the target stream in combination with the existing wild population should not exceed the natural stream's capacity. The manager can derive some guidance on stocking level, frequency and duration from a comparison of patient rearing densities with published densities. In the absence of data on stocking densities, releases should start at a conservative scale and gradually work up to the final release numbers based on monitoring information. This rule may not apply where the ESU is locked into a stable equilibrium at a density lower than its historic because of predation. In that case, it may be necessary to swamp the predators to increase the size of the ESU.

Use of Cautive Broodstock

Restoration of depleted stocks of salmon and steelhead has become a regularly occurring challenge for fishery managers and'it is likely that the number of salmon and steelhead stocks in need of restoration will increase. Planning and implementation of restoration programs are complicated, requiring knowledge and skills in many areas and a wide array of tools and strategies. Captive brood is an unconventional approach to broodstock management that has been used in commercial aquaculture and has had limited use in salmonid restoration projects.

Captive brood as used here refers to anadromous salmonids held in captivity through all or most of their life cycle in order to build a mature broodstock for artificial propagation. Captive broods may be reared entirely in fresh water or in a combination of fresh and salt water in a sequence that mimics the natural residence in those environments. The fish may be held in captivity from the egg through mature adult or wild juveniles may be captured and held to maturity. Captive brood has recently been applied to the recovery of the Red Fish Lake sockeye.

Captive brood technology has potential benefits and risks. Because the benefits and risks have not been evaluated through appropriate monitoring and evaluation, captive brood should be considered an experimental approach and used with caution and only in circumstances where there are no acceptable alternatives.

Evaluation

Once the alternative propagation strategies have been devised, the risks and benefits of each treatment should be evaluated. There are several approaches to this analysis. Part of the evaluation of risks and benefits of alternative propagation strategies can be completed though the use of a life-history model which RASP (1993) has developed specifically for that purpose.

3.4.2.6 Risk Analysis (Step 7)

Background

Artificial propagation involves use of technology to prevent extinction and increase natural production while limiting negative impacts on important natural attributes of the target and non-target stocks. Identifying and making provision to manage the risks of those impacts are important tasks in the planning of recovery programs. Risk analysis is a form of technology assessment. According to Brooks (1973), technology assessment should attempt to reduce the gap in opposing values that often generates conflict regarding the use of technology, determine the appropriate scale for the application of a technology, and promote innovation and adaptation in a technology. A fourth purpose is to prevent surprise failures or deviations from the expected results following the application of a technology (Timmerman 1986).

The use of propagation technology to restore or enhance natural production and to aid in the recovery of listed ESU's in the Columbia Basin is controversial. The controversy is fueled by divergent values held by agencies and organizations that possess political influence in the basin. Those values conflict in part because of the uncertainty surrounding the potential success or the negative side effects of propagation techniques. Supplementation may be associated in positive and negative ways with the past performance of conventional hatcheries. The gap in values that fuels the controversy can be reduced through knowledge. Some of the uncertainties can be reduced through the application of existing knowledge while some will require new research. As new information and understanding reduce the uncertainties, the issues and debate will become more focused on specific questions and a smaller number of less divergent values should emerge (Brooks 1973).

When setting the scale of a artificial propagation in the recovery of a listed ESU, the manager must take into account life histories and habitat quality, potential straying and introgression with non-target populations, the genetically effective population size (Ryman and Laikre 199 1), and economic efficiency (CBFWA 1991). The presence of multiple stability regions within a stock's production functions also influences project scale. The scale of a supplementation project is an important determinant of the nature and number of critical uncertainties and therefore is an important consideration in risk analysis.

Technologies with successful histories often slip into monocultures. Failure to recognize changing environments or public attitudes may lead to homogenous technologies, which are less innovative and adaptive (Brooks 1973). The use of artificial propagation to assist in the recovery of listed ESU's is a new application of the technology. Because this is a new application, there are a number of uncertainties associated with it making innovation and adaptation essential elements in recovery programs that employ artificial propagation. However, large investments in fixed physical facilities may be an impediment to innovation and adaptation in supplementation. Risk analysis must consider the design of fixed facilities and the flexibility of those facilities to "adapt to new information.

Surprise is **defined** as a **major** program failure or deviation **from** the expected and is often the product of too much reliance on unexamined assumptions regarding the use of a technology. Although we should try to conduct recovery programs and supporting research and monitoring in ways that minimize surprise, it is also important that we learn enough to act appropriately when surprise occurs.

All of the purposes of technology assessment listed above are relevant to the analysis of risk associated with the use of artificial propagation in recovery programs. In addition, the use of hatcheries in the recovery of listed **ESU's** carries with it another risk: the risk that the **ESU** will be extirpated as a result of poor hatchery practices.

Risk Assessment

Risk assessment is comprised of two tasks:

> **Estimating risk**. We propose that risk be estimated through a qualitative assessment **of** critical uncertainties and planning assumptions.
>
> **Managing** risk. The recovery plan must include a strategy for managing risk associated with the use of propagation through appropriate assumptions, research and risk containment monitoring.

Estimating Risk. Risk is broadly defined as the sum of the critical uncertainties associated with a project. The assessment of those risks is the qualitative weighing and comparison of the critical uncertainties for alternative treatments or objectives. An uncertainty is critical if the choice of assumption determines the success or failure of the recovery plan. The universe of critical uncertainties for a specific recovery project is the product of three factors: the functional relationship between the ESU and its habitat; the artificial propagation strategies applied to the system; and the recovery objectives (Figure 5). Each recovery plan will produce a unique set of critical uncertainties. Once the recovery plan is implemented, research or monitoring are employed to reduce the risk of critical uncertainties.

Critical uncertainties should be identified for all dimensions of the management objective, i.e., long-term fitness, reproductive success, ecological interactions, post-release survival, and the numerical production targets. Tables 6a-e are worksheets designed to aid in the risk analysis for each dimension of the objective. The worksheets call for a list of critical uncertainties (if there are any); their potential impact on the specific **dimension** of the objective; the overall impact of the project; the initial (planning) assumptions; and a description of how the uncertainty (risk) will be managed through monitoring and evaluation. The tables call for seven categories of information:

> **Management Objective** of the management objective is analyzed in a separate table. For example, in Table 6b the target for post release survival is described and in Table 6c the target for reproductive success is described.

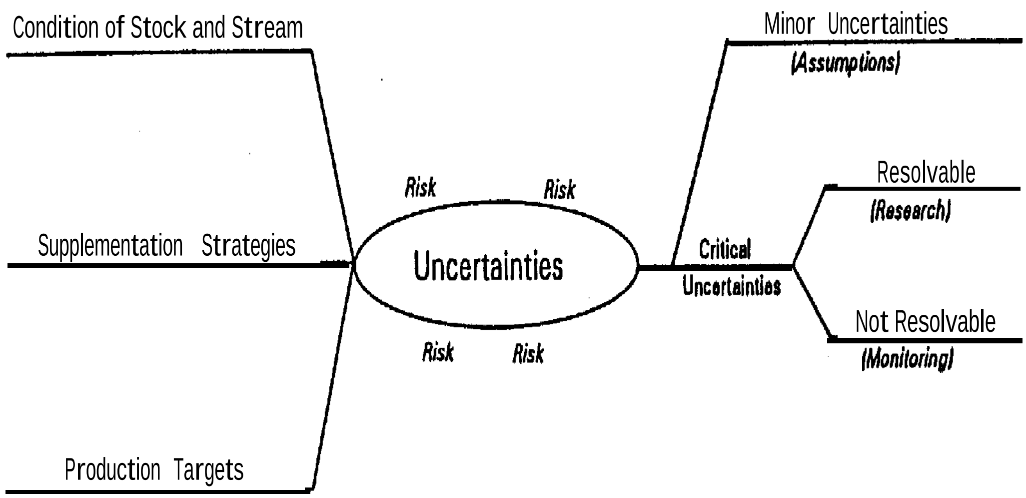

Figure 5, Schematic representation of the origin and treatment of supplementation uncertainties.

Table **6a.** Risk Analysis Numerical Targets Work Sheet

MANAGEMENT OBJECTIVE

Numerical Targets: ______________________________

Treatment Alternative: ______________________________

Critical Uncertainty	Potential Imoact on Specific Dimension of Objective	Overall Imoact on Project	Initial Assumptions	M & E

Table **6b.** Risk Analysis Post Release Survival Work Sheet

MANAGEMENT OBJECTIVE

Post Release Survival: ______________________________

Treatment Alternative: ______________________________

Critical Uncertainty	Potential Impact on Specific Dimension of Objective	Overall Impact on Project	Initial Assumptions	M & E

Table 6c. Risk Analysis Reproductive Success Work Sheet

MANAGEMENT OBJECTIVE

Reproductive Success: ______________________________

Treatment Alternative: ______________________________

____

____

Critical Uncertainty	Potential Impact on Specific Dimension of Objective	Overall Imoact on Project	Initial Assumotions	M & E

Table 6d. Risk Analysis Ecological Interactions Work Sheet

MANAGEMENT OBJECTIVE

Ecological Interactive: ______________________________

Treatment Alternative: ______________________________

____

____

Critical Uncertainty	Potential Impact on Specific Dimension of Objective	Overall Impact on Protect	Initial Assumptions	M & E

Table 6e. Risk Analysis Long Term Fitness Work Sheet

MANAGEMENT OBJECTIVE

Long Term Fitness: ______________________________

Treatment Alternative: ______________________________

____

____

Critical Uncertainty	Potential Impact on Specific Dimension of Objective	Overall Impact on Project	Initial Assumptions	M & E

Treatment Alternative The proposed treatment is described by listing all six of the basic elements (see section 3.4.2.5). If more than one treatment alternative is being analyzed, each requires the completion of a separate set of Tables 6a-e.

Critical Uncertainties Critical uncertainties associated with **each dimension** of **the** objective and each treatment alternative are listed.

Initial Assumption For each critical uncertainty, describe and document the initial assumptions that led to the choice of specific treatments. For example, the system planning model discounts the survival of hatchery reared fish by 50% relative to wild fish. To achieve the numerical objective of the recovery plan, however, post-release survival must be increased to 80% of the survival of wild fish. In this case, the increase in survival is to be achieved through innovative rearing practices. The critical uncertainty is the cause of the survival differential between hatchery and wild fish. The assumption is the relationship between innovative rearing practices and survival.

Potential Impact on the Specific Dimension of the Obiective. For each critical uncertainty, describe the potential impact of a false assumption on the specific dimension of the objective.

Overall **Impact on the Obiective** In this part of the table, the impact of a false assumption on the overall recovery objective is described. From the previous example, the impact of a failure to increase survival of hatchery fish, on the ability to recover the ESU is evaluated, i. e., recovery may still be possible but take longer.

Monitoring and Evaluation Briefly sketch the research or monitoring that will be implemented to resolve or contain the risk associated with each uncertainty.

The purpose of risk assessment is to give the decision maker technical advice regarding the probability of achieving the recovery objectives through artificial propagation. Risk assessment is tied to decision making, however, there is a clear distinction between the two. Risks associated with the use of artificial propagation can be determined through an objective, scientific process and the consequences of alternative choices can described through analysis. However, there is no scientific basis for making the final decision i.e., deciding how much risk to accept (Brooks 1973). While the final decision has to include consideration of the scientific analysis, it must also incorporate other considerations: economics, community values and political processes, for example.

Managing Risk False assumptions regarding a critical uncertainties can cause the failure of a recovery program. The risk associated with the critical uncertainties must be "managed" to reduce their potential negative effect and improve the probability that artificial propagation will contribute to recovery. Risk management is accomplished in three ways:

- Initially, the critical uncertainties listed in Tables 6a-e are managed through reasonable assumptions. The assumptions should be based on a review of the literature and they should be subjected to a review by qualified experts.

- The risks associated with some uncertainties can be removed or reduced by research (Figure 5). A brief outline of the research design is called for in Tables 6a-e. Section (3.4.2.7) provides guidelines for on the design of research and monitoring.

- Some uncertainties may not be amendable to research (Figure 5). The risks associated with those uncertainties are managed through monitoring designed to contain risk by giving early warning of a problem i.e., of a false assumption.

The recovery plan must show how each critical uncertainty will be "managed" either through research or monitoring.

3.4.2.7 Monitoring and Evaluation

Background

The objectives of monitoring and evaluation (M&E) are to: a) reduce or remove the critical uncertainties identified in Tables 6a-e and thereby improve the probability of successful recovery (risk management), b) to monitor population variables that give warning of an error in planning assumptions (risk containment monitoring), and c) to document the return on project investment (accountability).

Few stream/stock systems that are the subject of recovery plans will have sufficient information to complete all the steps described in the previous sections of this report, particularly Tables A. 1-A.3 in Appendix A. In many recovery programs, the risk of extinction may be too high to delay action while more information is collected. However, all the steps need not be completed before implementation. The recovery plan should address all the steps with existing information, whether that information is qualitative or quantitative. When implementation must proceed with missing information, the planning steps (Figure 3) become an iterative process which is driven by information obtained through M&E. Key elements in the process i.e., patient-template analysis, diagnosis, and risk analysis are repeated at regular intervals to incorporate new information. The objective of an iterative planning process is to eventually reduce or eliminate the critical uncertainties. In this context, planning is not a one-time activity but it becomes an important part of the M&E, at least until the uncertainties are resolved. The iterative process should be subjected to regular peer review.

Design Considerations

The generally accepted approach to scientific investigations includes the sequence:

- Devise alternative hypotheses

- Devise the experiments to exclude one or more hypotheses

- Carry out the experiment, evaluate the results, and then recycle the procedure (Platt 1964).

The M&E for a recovery program begins with the patient-template analysis which leads to the list of critical uncertainties (Tables 6a-e). The design of the M&E is initiated by the derivation of hypotheses from the patient-template analysis critical uncertainties. For stream/stock systems with insufficient baseline information, preliminary surveys may have to be completed. Ward (1978) recommends field surveys to estimate the structure and function of the system prior to the formulation of hypotheses and the design of M&E. A failure to carry out the survey or a survey that merely catalogues rather than determines functional relationships often restricts the success of the M&E (Ward 1978).

When formulating hypothesis, its important to consider that ecological questions, particularly those dealing with salmon production and productivity, are not easy to partition into mutually exclusive, alternative hypotheses. Factors that determine production often have a large degree of interaction, however, hypotheses are often framed as though they are mutually exclusive. When independence is incorrectly assumed, hypothesis testing can lead to misleading conclusions (Quinn and Dunham 1983).

Conventional wisdom seems to suggest that experimental design is the formulation a series of null and alternative hypotheses along with appropriate statistical tests. While the development of hypotheses is critical to the overall scientific approach, another important purpose of experimental design, which is often overlooked, is to identify and remove irrelevant sources of variability thereby increasing the power of the test of the null hypothesis (Cohen 1988). For a discussion of experimental design in fisheries management including alternative approaches, see McAllister and Peter-man (1992).

Statistical Power

Conventional analysis in fisheries attempts to reject a null hypotheses which is usually stated as no effect. For example, a null hypothesis for supplementation might be: There is no difference in smolt-to-adult survival between naturally produced and artificially produced salmon. When a null hypothesis is rejected the significance level (cc) of the test is also reported. Failure to reject the null hypothesis is not equivalent to accepting it (Peterman 1989). When the data fail to reject the null hypothesis of no effect, managers often fail to report power of the test (Peterman 1990) which is the probability that the test would lead to a rejection of the null hypothesis (Cohen

1988). If the probability of rejecting the, null hypothesis is low, the failure to report the 'power of the test can lead managers to erroneously accept the null hypothesis (Peterman 1990).

To illustrate the point above, consider this example: A manager is experimenting with a new release timing and size to increase smolt-to-adult survival of supplemented fish. The objective is to increase the survival of supplemented fish to equal the survival of naturally produced fish. The data fails to reject the null hypothesis (no differences in survival) and the manger assumes the experiment was a success and survival of supplemented and natural fish is equivalent. However, because of a small sample size and high sampling variability, the power of the test is low. In this case the manager may have erroneously terminated the experiment when in fact the survival of supplemented fish was not changed and remains below that of natural fish.

The importance of statistical power lies in its capacity to minimize the potentially harmful results of decisions based on erroneous conclusions. Incorporating statistical power into the experimental designs improves the quality of experiments and informs decision makers of the risks associated with experimental results. Some variables such as survival and adult abundance are difficult to measure with high levels of statistical power. DeLibero (1986) concluded that the best one could expect from survival studies of hatchery fish is a coefficient of variation of 25%. In most cases, over reasonable experimental periods, that level of variation would lead to low statistical power. Lichatowich and Cramer (1979) found that studies of survival and abundance may require 20 to 30 years to produce an 80% chance of detecting a 50% change.

Power of an experiment can be improved by the choice of variables to be measured. Although survival and abundance of adult salmon and steelhead are important variables that can measure the performance of artificial propagation, our inability to measure them with reasonable statistical power suggests the need to search for alternatives (Lichatowich and Cramer 1979). Appropriate performance measures such as size and timing of juvenile migration (Lichatowich and Cramer 1979) could serve as surrogates for survival and abundance in some experimental designs. Appropriate performance measures could give an early indication of the success of recovery strategy or indicate the need for corrective action long before the outcome in terms of returning adults can be determined.

M&E Design

To improve the probability of success of supplementation projects, the risk associated with critical uncertainties needs to be managed by reasonable assumptions followed by research and/or monitoring. Prior to the design of research or monitoring projects, critical uncertainties should be subjected to a qualitative scoping process (Table 7) to establish priorities and set guidelines for the experimental design.

Table 7. Scoping process for critical uncertainties associated with the use of propagation in recovery plans.

FACTORS	COMMENTS
critical Uncertainties	List initial assumptions (see Tables 6a-6e) used in developing the propagation options in the recovery plan.
Applicability	Describe the relationship between the uncertainty and recovery objectives (see Tables 6a-6e).
Prioritize critical uncertainties	Determine the relative importance of the critical uncertainties. Some uncertainties can be evaluated through the RASP (1993) model; others will have to be ranked by qualitative weighing of the potential impact on objectives.
Hypotheses	Where possible convert the assumptions associated with each uncertainty to testable hypotheses or monitoring elements.
Feasibility	State the feasibility of testing the hypotheses: identify sources of variability, baseline data needs, controls, blocks, etc.
Statistical Considerations	State the desired level of statistical power. How reliable do the research results have to be? Can the desired level of statistical power be achieved?
Scope	List species, stocks, strategies and areas within the subbasin for which the uncertainty is critical.
Risks	Will the experiments pose a biological risk?
Opportunities	Are there other projects better suited to conduct the experiments? Can the results be extrapolated to other projects? Do we need to use the listed ESU to conduct the experiments.
Remaining needs	Questions and information needs not expected to or unlikely to be met under current plans.

Once the project has undergone preliminary scoping, those experiments or monitoring that are identified as high priority and feasible will require statistical design. Green (1979) gives ten basic statistical rules for the design of environmental studies. These same rules are also appropriate for the design of M&E in recovery plans.

1. Be able to state concisely to someone else what question you are asking. Your results will be only as coherent and as comprehensible as your initial conception of the problem.

2. Take replicate samples within each combination of time, location, and any other controlled variable. Differences among can only be demonstrated by comparison to differences within.

3. Take an equal number of randomly allocated replicate samples for each combination of controlled variables. Putting samples in representative or typical places is not random sampling.

4. To test whether a condition has an effect, collect samples both where the condition is present and where the condition is absent but all else the same. An effect can only be demonstrated by comparison with a control.

5. Carry out some preliminary sampling to provide a basis for evaluation of sampling design and statistical analysis options. Those who skip this step because they do not have enough time usually end up losing time.

6. Verify that your sampling device is sampling the population you think you are sampling, with equal and adequate efficiency over the entire range of sampling conditions to be encountered. Variation in efficiency of sampling from area to area biases among-area comparisons.

7. If the area to be sampled has a large-scale environmental pattern, break 'the area up into relatively homogenous subareas and allocate samples to each in proportion to the size of the subarea. If it is an estimate of total abundance over the area that is desired, make the allocation proportional to the number of organisms in the subarea.

8. Verify that your sample unit size is appropriate to the size, densities, and spatial distribution of the organisms you are sampling. Then estimate the number of replicate samples required to obtain the precision you want.

9. Test your data to determine whether the error variation is homogenous, normally distributed, and independent of the mean, If it is not, as will be the case for most field data, then: (a) appropriately transform the data, (b) use a distribution-free (nonparametric) procedure, (c) use an appropriate sequential sampling design, or (d) test against simulated H_o data

10. Having chosen the best statistical method to test your hypothesis, **stick** with the result. An unexpected or undesired result is not a valid reason for rejecting the method and hunting for a better one.

REFERENCES

Aho, RS., G.L. Concannon, J.S. Ziller, S. Pribyl, R,K, Schroeder, K. Anderson, R Hill and D. Ratliff. 1979. An ecological and fish cultural study of Deschutes River salmonids. Oregon Department of Fish and Wildlife, Annual Progress Report, Fish Research Project F-88-R-9, Portland, OR.

Allendorf, F.W., J.E. Lannon, and L.A. Riggs. 1990. Clarification of wild/natural production issues in the production principles. Submitted to The Northwest Power Planning Council, September 18, 1990.

Allendorf, F.W. and N. Ryman. 1987. Genetic management of hatchery stocks. In N. Ryman and F. Utter (Eds.), ***Population Genetics and Fishery Management,*** U. of Washington Press, 141-159.

Bachman, R.A. 1984. Foraging behavior of free-ranging wild and hatchery brown trout (*Salmo trutta*) in a stream. ***Trans. Am. Fish. Soc.*** 113: l-32.

Bjomn, T.C. 1978. Survival, production and yield of trout and chinook salmon in the Lemhi River, Idaho. Forest, Wildlife and Range Experiment Station, University of Idaho, Bulletin No. ***27.*** Moscow. ID.

Bjornn. T.C. and D.W. Reiser. 1991. Habitat requirements of salmonids in ***streams. Am. Fish. Soc. Spec. Pub.*** 19: 83-138.

Bowles, E. and E. Leitzinger. 1991. Salmon supplementation studies in Idaho rivers: Experimental design. Idaho Dept. of Fish and Game, Boise, ID, Project 89-098. 166 p.

Bradshaw, A.D. 1990. Restoration: An acid test for ecology. ***Restoration Ecology.*** Eds. W.R. Jordan III, M.E. Gilpin, and J.D. Aber. Cambridge University Press, Cambridge. 23-29.

Brooks, H. 1973. Technology assessment ***as*** a process. ***Int. Soc. Sci. J.*, 25:3 *253-262.***

Busack, C. 1990. Yakima/Klickitat production project genetic risk assessment. Manuscript. Genetics Unit, Washington Department of Fisheries, Olympia, WA. 21 p.

Cederholm, C.J., L.R. Reid, and E.O. Salo. 1980. Cumulative effects of logging road sediment on salmonid populations in the Clearwater River, Jefferson County, Washington. Contribution No. 543, College of Fisheries, University of Washington, Seattle, 35 p.

Cohen, J. 1988. ***Statistical Power Analysis for the Behavioral Sciences.*** 2nd Edition. Lawrence Erlbaum Assoc., Publishers. Hillsdale, NJ. 567 p.

Columbia Basin Fish and Wildlife Authority. 1991. Integrated system plan. Portland, OR ***527*** p.

Congleton, J.L., T.C. Bjomn, B.H. Burton, B.D. Watson, J.I. Irving, and RR Ringe. 1985. Effects of handling and crowding on the stress response and viability of chinook salmon parr and smolts. Bonneville Power Administration, Division of Fish and Wildlife, Project 82-5, Portland, OR.

Currens, K.P., C.A. Busack, G.K. Meffe, D.P. Phillip, E.P.Pister, F.M. Utter, and S. Youndt. 1991. A hierarchical approach to conservation genetics and production of anadromous salmonids in the Columbia River Basin. Draft report from the Sustainability Workshop, January 24-26, 1991. Northwest Power Planning Council. Portland, OR. 30 p.

DeLibero, F.E. 1986. A statistical assessment of the use of the coded wire tag for chinook *(Oncorhynchus tschawytschu)* and coho *(0. kisutch)* studies. Ph.D. Dissertation, Univ. of Wash., Seattle, WA 227 p.

Doyle, RW. and A.J. Talbot. 1986. Artificial selection on growth and correlated selection on competitive behavior in fish. ***Can. J. Fish. Aquat. Sci.*** 43: 1059-1064.

Everest, F.H. 1973. Ecology and Management of summer steelhead in- the Rogue River. Oregon State Game Commission, Fishery Research Report No. 7, 48 p.

Falconer, D.S. ***1970. Introduction to Quantitative Genetics.*** The Ronald Press Company, New York, 356 p.

Falconer, D.S. 1981. ***Introduction to quantitative genetics,*** 2nd ed. Longman, London, U.K., 340 p.

Fast, D.E., J. Hubble, M. Kohn and B. Watson. 1991. Yakima spring chinook enhancement study: Final Report. Bonneville Power Administration, Division of Fish and Wildlife, Project 82-16.

Fenderson, O.C, W.H. Everhart, and K.M. Muth. 1968. Comparative agonistic and feeding behavior of hatchery-reared and wild salmon in aquaria. ***J. Fish. Res. Bd. Can.*** 25:1-14.

Frazer, N.B. 1992. Sea turtle conservation and halfway technology. ***Conservation Biology*** 6:2: 179-184.

Goodman, M.L. 1990. Preserving the genetic diversity of salmonid stocks: a call for federal regulation of hatchery programs. ***Environmental Law*** 120: 111-166.

Green, R.H. ***1979. Sampling Design and Statistical Methods for Environmental Biologists.*** Wiley and Sons, New York.

Hall, J.D. and R.L. Lantz. 1969. Effects of logging on the habitat of coho salmon and cutthroat trout in coastal *steams. In Symposium on Salmon and Trout in Streams.* T.G. Northcote (Ed.) 355-375.

Hard, J.J., R.P. Jones Jr., M.R. Delarm, and R.S. Waples. 1992. Pacific salmon and artificial propagation under the endangered species act. National Marine Fisheries Service, Technical Memorandum NMFS-NWFSC-2, 56 p.

Hume, .M.B. and E.A. Parkinson. 1988. Effects of size at and time of release on the survival and growth of steelhead fry stocked in streams. N. *Am. J. Fish. Manage. 8: 50-57.*

Idaho Department of Fish and Game. 199 1. Idaho's anadromous fishery management plan. Boise, ID.

Ihssen, P.E., H.E. Booke, J.M. Casselman, J. M&lade, N.R. Payne and F.M. Utter. 1981. Stocj identification: materials and methods. *Can. J. Fish. Aquat. Sci. 38:* 1838-1855.

Kapuscinski, A.R. 1991. Genetic analysis of policies and guidelines for salmon and steelhead hatchery production in the Columbia River Basin. Report prepared for the Northwest Power Planning Council [Agreement 90-037]. January 9, 1991.

Kapuscinski, A. R., C. R. Steward, M. L. Goodman, C. C. Krueger, J. H. Williamson, E. Bowles and R. Carmichael. 199 1. Genetic conservation guidelines for salmon and steelhead conservation. Draft report from the Sustainability Workshop, January 24-26, 199 1. Northwest Power Planning Council. Portland, OR. 51 p.

'Lande, R and G.F. Barrowclough. 1987. Effective population size, genetic variation, and their use in population management. *In Viable Populations for Conservation,* M.E. Soule (Ed.), Cambridge University Press, New York, 87-123.

Lichatowich, J. and S. Cramer. 1979. Parameter selection and sample sizes in studies of anadromous salmonids. Oregon Dept. of Fish and Wildlife Information Report Series, Fisheries Number 80-1, Portland, OR. 25 p.

Lynch, M. 1991. The genetic interpretation of inbreeding depression and outbreeding depression. *Evolution 45: 622-629.*

Mace, P.. 1983. Bird predation on the Big Qualicum River, Vancouver Island, Canada *Can. Tech. Rep. Fish. Aquat. Sci. No.* 1176, pp l-79.

Marnell, L.F. 1986. Impacts of hatchery stocks on wild populations. pp 339-347 *in* R.H. Stroud, editor, *Fish culture in fisheries management.* American Fisheries Society, Bethesda, Maryland.

McAllister, M.K. and R.M. Peterman. 1992. Experimental design in the management of fisheries: A review. ***North Am. J. of Fish. Man.* 12:11-18.**

McIntyre, J.D., R.R Reisenbichler, J.M. Emlen, R.L. Wilmot and J.E. Firm. 1989. Predation of Karluk River sockeye salmon by coho salmon and char. ***Fishery Bulletin*** 86: 611-616.

Meffe, G.K. 1986. Conservation Genetics and the management of endangered fishes. ***Fisheries* 11:(1):14-23.**

Meffe, G.K. 1992. Techno-arrogance and halfway technologies: Salmon hatcheries on the Pacific coast of North American. ***Conservation Biology,* 6:3 *350-354.***

Miller, W.H., T.C. Coley, H.L. Burge and T.T. Kisanuki. 1990. Analysis of salmon and steelhead supplementation: emphasis on unpublished reports and present programs. Part 1 ***in*** W.H. Miller, editor, Analysis of salmon and steelhead supplementation, Parts 1-3. Technical Report 88-100, Bonneville Power Administration, U.S. Department of Energy, Portland, OR.

Monitoring and Evaluation Group. 1989. Salmon and steelhead system planning documentation. Northwest Power Planning Council, Portland, Oregon,

Mousalli, E. and M. Hillbom. 1986. Optimal stock size and harvest rate in multistage life history models. Can. *J. FIsh. Aquat. Sci.* 43: 135-141.

Nelson, K. and M. Soule. 1986. Genetical conservation of exploited fishes. ***In Population Genetics and Fishery Management,*** N. Ryman and F. Utter, **(Eds.),** University of Washington Press, Seattle, 345-368.

Peterman, R.M. 1977. A simple model that causes collapsing stability regions in exploited salmon populations. ***J. Fish. Res. Bd.*** Can. 34: 1130-1142.

Peterman, R.M. 1987. Review of the components of recruitment of Pacific salmon. pp 417-429 ***in*** M.J. Dadswell, R.J. Klauda, C.M. Moffitt, RL. Saunders, RA. Rulifson and J.E. Cooper, eds. Common strategies of anadromous and catadromous fishes. Am Fish. Soc. Symposium 1

Peterman, R.M. and M. Gatto. 1978. Estimation of functional responses of predators on juvenile salmon. ***J. Fish. Res. Bd. Can.* 35: *797-808.***

Petersen, J.H. and D.L. DeAngelis. 1992. Functional response and capture time in an individual-based model: predation by northern squaw&h (*Pteichocheilus oregonensis*) on juvenile salmon. Can. ***J. Fish. Aquat. Sci. 49:*** 2551-2565.

Petrosky, C.E. 1984. Competetive effects from stocked catchable-sized trout on wild trout population dynamics. Doctoral dissertation, University of Idaho, Moscow, Idaho.

Platt, J.R. 1964. Strong inference. ***Science,* 146:3642** 347-352.

Quinn, J.F. and A.E. Dunham. 1983. On hypothesis testing in ecology and evolution. ***The A m erican Naturalist,*** 122: 5 602-6 17.

RASP. 199 1. Regional assessment of supplementation project. Annual Progress Report, December 3 1, 1991. Bonneville Power Administration, Portland, Oregon.

RASP. 1993 Regional assessment of supplementation project. Final Completion Report, Bonneville Power Administration, Portland, Oregon.

Raymond, H.L. 1988. Effects of hydroelectric development and fisheries enhancement on spring and summer chinook salmon and steelhead in the Columbia River Basin. N. Am. J. Fish. Manage. 8: l-24.

Regier, H.A. and G.L. Baskerville. 1986. Sustainable redevelopment of regional ecosystems degraded by exploitive development. ***In* W.C.** Clark and RE. Munn ***(eds), Sustainable Development of the Biosphere.*** Cambridge University Press, Cambridge, MA, 75-103.

Reimers, P.E. 1973. The length of residence of juvenile fall chinook salmon in Sixes River, Oregon. Research Reports of the Fish Commission of Oregon. **4:2** 43 p.

Reimers, P.E. 1979. Success in a hatchery program with fall chinook salmon by simulating the natural life history of ***the*** stock. ***Progressive Fish Culturist* 41:4**.

Reisenbichler, R.R. and J.D. McIntyre. 1986. Fish culture in fisheries management. In ***Proceedings of a Symposium on the Role of Fish Culture in Fisheries Management,*** at Lake Ozark, Missouri, March **31-April** 3, 1985. Ed. R.H. Stroud. 365-374.

Rich, W.H. 1938. Local Populations and Migration in Relation to the Conservation of Pacific Salmon in the Western States and Alaska. Contribution No. 1, Fish Commission of the State of Oregon. 6 p.

Ricker, W.E. 1972. Hereditary and environmental factors affecting certain **salmonid** populations. ***In The Stock Concept in Pacific Salmon.*** Ed RC. Simon and P.A. **Larkin,** MacMillan Lectures in Fisheries, University of British Columbia. 19-160.

Ryman, N. and L. Laikre. 1991. Effects of supportive breeding on the genetically effective population size. ***Conservation Biology* 5:325-329**.

Skud, E.B. 1982. Dominance in fishes: the relation between environment and abundance, ***Science*** 216: 133-149.

Specker, J.L. and C.B. Schreck. 1980. Stress responses to transportation and fitness for marine survival in coho salmon (*Oncorhynchus kisutch)* smolts. Can. *J. Fish. Aquat. Sci. 37: 765-769.*

Snyder, N.F.R. and H.A. Snyder. 1988. Biology and conservation of the California condor. In *Current Ornithology,* D.M. Power (Ed), Plenum Press, New York, 175-267.

Steward, C. R. and T. C. Bjornn 1990. Supplementation of salmon and steelhead stocks with hatchery fish: A synthesis of published literature. U.S. Department of Energy, Bonneville Power Administration Project 88 -100. Portland, OR

Swain, D.P. and B.E. Riddell. 1990. Variation in agonistic behavior between newly emerged juveniles from hatchery and wild populations of coho salmon, *Oncohynchus kisutch. Can. J. Fish. Aquat. Sci. 47: 566-571.*

Symons, P.E.K. 1969. Greater dispersal of wild compared with hatchery-reared juvenile Atlantic salmon released in *streams. J. Fish. Res. Bd. Can. 26:* 1867-1876.

Taylor, E.B. 199 1. A review of local adaptations in Salmonidae, with particular reference to Pacific and Atlantic salmon. *Aquaculture* 98: 185-207.

Thompson, G.G.. 1991. Determining minimal viable populations under the Endangered Species Act. U.S. Dept. Commer., NOAA Tech. Memo. NMFS F/NWC-198, 78 pp.

Thompson, W. F. 1959. An approach to population dynamics of the Pacific red salmon. *Trans. Am. Fish. Soc.* 88:3 *206-209.*

Timmerman, P. 1986. Mythology and surprise in the sustainable development of the biosphere. *In* W.C. Clark and R.E. Munn, *eds. Sustainable Development of the Biosphem,* International Inst. for Applied Systems Analysis, Laxenburg, Austria, 435-452.

United States Department of the Interior, Fish and Wildlife Service. 1990. Policy and guidelines for planning and coordinating recovery of endangered and threatened species.

Wade, Mark. 1986. The relative effects of ceratomyxa shasta on crosses of resistant and susceptible stocks of summer steelhead. M.S. Thesis, Oregon State University, Corvallis, Oregon, 1986.

Waples, RS. 1991a. Pacific salmon, *Onchorhynchus* spp., and the definitions of "species" under the Endangered Species Act. *Mar. Fish. Rev.* 53(3): 1 l-22.

Waples, R.S. 1991 b. Genetic interactions between hatchery and wild salmonids: Lessons from the Pacific *Northwest. Can. J. Fish. Aquat. Sci.* 48(Suppl. 1): 124-133.

Ward, D.V. 1978. ***Biological Environmental Impact Studies: Theory*** and ***Methods.*** Academic Press, 157 p.

Wood, C.C. 1984. Foraging behavior of common mergansers ***(Mergus merganser)*** and their dispersion in relation to the availability of juvenile Pacific salmon. Doctoral dissertation. University of British Columbia, Vancouver.

APPENDIX A

GUIDELINES FOR COMPLETING A TEMPLATE/PATIENT ANALYSIS

Tables A.l-A.3 of Appendix A describe the three important life history stages of spawning and incubation, rearing, and migration in terms of habitat, timing, survival and demographics. The tables were constructed as a partial example to illustrate how the analysis of life histories (Figure 3, Table 4) might be approached. Completing Tables A. l-A.3 requires a significant level of understanding of the relationships among the stock's life histories, its habitat, and production. Under the policy of adaptive management, it is not necessary complete the patient-template analysis to implement a project, but the manager must supply what is known in all the information categories. In many cases the only information available to the manager to complete the tables will be qualitative. Information gaps in Tables A. 1 -A.3 leads to uncertainties which are addressed in the risk analysis and project monitoring and evaluation. As new information is obtained, the gaps are reduced and uncertainties, risks and project methodology are modified as appropriate. For those projects that are implemented with a great deal of uncertainty, planning becomes an iterative process.

A brief description of the information called for under each life history is given below. Where appropriate, the manager should indicate whether limiting factors are density-independent or density-dependent.

Spawning and Incubation

Tables A.1a-A.1b require the information described in this section.

Life History Type is a designation given to a group of fish whose spawning time or location, rearing habitat preference and/or migration timing are similar within the group. There may be multiple life histories within each stock. The tables should be expanded so that there is a line for each life history.

Smolt Age describes age at smoltification: 0,1,2,or mixed.

Habitat describes the area in the subbasin or tributary where fish of a specific life history type spawn.

Habitat Quantity is either a physical measure of the habitat area or an estimate of the percent of the total area available or suitable for spawning.

Habitat Quality is an estimate of the biophysical condition of the habitat relative to survival or productivity. For spawning habitat, quality might be described in terms of gravel composition (% fines) or the stability of the streambed (frequency and depth of scour).

Timing gives the interval (dates) when spawning occurs and the peak (Julian Week) of spawning activity.

Incubation Survival gives the survival from egg to fry. This might be extrapolated from the relationship between survival and percent fines in the gravel (Cederholm et al. 1980 and Hall and Lantz 1969).

Prespawning Mortality can be estimated directly from surveys or indirectly from counts at dams or diversions and redd counts adjusted for redd:fish ratio. Indicate if disease is a mortality factor.

Swcies Interaction is an estimate of the effects of competitors or predators on successful spawning and incubation.

Age Structure is simply the age distribution of the spawning population.

Sex Ratio **and Fecundity** are self explanatory.

Life History Summary records summary comments and observations regarding a single life history type across all factors influencing spawning success. Conclusions such as the apparent limiting factor can be entered here.

Stock Summary records summary comments and observations across all life history types for a given factor influencing spawning success.

Rearing

Tables A.2a-A.2b require the information described below:

Life History Type. See description under spawning and incubation.

Habitat See explanation under spawning and incubation above.

Habitat Quantity. See explanation under spawning and incubation above.

Habitat Quality is an estimate of the physical quality of the rearing habitat relative to survival and production. For rearing, measures of habitat quality might include: the pool to riffle ratio, temperature, flows (absolute and seasonal patterns), stream structure, condition of the riparian zone, winter refugia, etc.

Timing gives the interval (dates) when rearing occurs in the specific section/area of the subbasin or tributary identified under Habitat.

Density gives the rearing density of juveniles. Appendix B gives rearing densities of juvenile chinook and steelhead reported in the literature for comparative evaluation.

Growth gives the size at the end of the interval (spring/summer or fall/ winter).

Survival gives the survival to the end of the interval. Appendix B gives survivals of juvenile chinook and steelhead reported in the literature for comparative evaluation.

Species Interaction is an estimate of the effects of predators or competitors on rearing.

Life History Summary records summary comments and observations across all factors influencing rearing success. This might include a comparative evaluation of rearing density and survival between the target stream and values reported in the literature (Appendix B).

Stock Summary records summary comments and observations across all life history types for a given component of rearing success.

Migration

Tables A.3a-A.3c present information related to migration at different stages. The information is described below:

Life History Type. **See** description under spawning and incubation.

Hydrograph describes the relationship between flow patterns and migration.

Timing describes the normal timing of migration.

Survival/Blockages describes impediments to migration (except mainstem passage problems) and problems causing mortality during migration. For example, an impassible dam or mortality at irrigation diversions would be listed here.

Species Interaction is an estimate of the effect of competitors or predators on migration. For example, predation by squaw fish would be described.

Mainstem Passage gives the effect of mainstem passage problems on survival of smolt migrants.

Ocean Distribution gives the ocean distribution of the stock.

Fisheries Interception gives the points of fishing interception of the stock in the ocean, estuary and river.

__**Life History Summary**__ records summary comments and observations across all factors influencing migration success.

__**Stock Summary**__ records summary comments and observations across all life history types for a given component of migration success.

As stated above, in **very** few if any cases, will the manager be able to complete the template/patient analysis shown in Tables A. l-A.3. At first, the task might appear impossible and the manager may be tempted to skip it altogether. However, this is an important step in the planning process and even a partial analysis will be worth the effort. Any attempt at historical reconstruction will include some thoughtful speculation and will be subject to debate and criticism. In the absence of hard information, a review of the literature, **thoughtful** speculation, and debate are important ingredients of successful planning and the identification of the best supplementation strategies. Information that can be used to describe the template may be obtained from the following:

- __Historical reoorts from the target stream/stock__. In the ideal situation, the manager has sufficient empirical observations from historical reports to complete the template analysis.

- __Historical reports from similar streams/stocks__. Appropriate information from nontarget streams/stocks can be used in the template analysis.

- __Back calculate from published literature.__ The template can be back calculated from published reports which describe the life histories of the target or a similar nontarget stream/stock at a point between the healthy condition and the current state of degradation.

- __Back calculate from the patient.__ In some cases, the description of the patient will provide insight help in completing part of the template analysis.

Table A, 1 a, Template/patient analysis - spawning and incubation,

life History Type	Smolt Age	SPAWNING AND INCUBATION					
		Habitat	Habitat Quantity	Habitat Quality	Timing	Incubation Survival	Prespawning Mortality
		Template					
		Patient					
		Template					
		Patient					
		Template					
		Patient					
STOCK SUMMARY							

Table A.1b. Template/patient analysis - spawning and incubation,

Life History Type	SPAWNING AND INCUBATION				
	Species interactions	Age Structure	Sex Ratio	Fecundity	Life History Summary
	Template				
	Patient				
	Template				
	Patient				
	Template				
	Patient				
STOCK SUMMARY					

Table A.2a. Template/patient analysis - spring/summer rearing.

Life History Type	SPRING/SUMMER REARING								
	Habitat	Habitat Quantity	Habitat Quality	Timing	Density	Growth	Survival	Species Interactions	Life History Summary
	Template								
	Patient								
	Template								
	Patient								
	Template								
	Patient								
	Template								
	Patient								

Table A.2a. cont'd.

Life History Type	SPRING/SUMMER REARING								
	Habitat	Habitat Quantity	Habitat Quality	Habitat Timing	Density	Growth	Survival	Species Interactions	Life History Summary
	Template								
	Patient								
	Template								
	Patient								
STOCK SUMMARY									

Table A.2b. Template/patient analysis - fall/winter rearing.

Life History Type	FALL/WINTER REARING								
	Habitat	Habitat Quantity	Habitat Quality	Timing	Density	Growth	Survival	Species Interactions	Life History Summary
	Template								
	Patient								
	Template								
	Patient								
	Template								
	Patient								
	Template								
	Patient								

Table A.2b. cont'd.

Life History Type	FALL/WINTER REARING								
	Habitat	Habitat Quantity	Habitat Quality	Timing	Density	Growth	Survival	Species Interactions	Life History Summary
	Template								
	Patient								
	Template								
	Patient								
STOCK SUMMARY									

Table A.3a. Template/patient analysis - presmolt migration

Life History Type	PRESMOLT MIGRATION					
	Hydrograph	Timing	Survival/ Blockages	Species Interaction'		Life History Summary
	Template					
	Patient					
	Template					
	Patient					
	Template					
	Patient					
STOCK SUMMARY						

Table A.3b. Template/patient analysis - smolt migration

Life History Type	SMOLT MIGRATION					
	Hydrograph	Timing	Survival/ Blockages	Species Interaction	Mainstem Passage	Life History Summary
	Template					
	Patient					
	Template					
	Patient					
	Template					
	Patient					
STOCK SUMMARY						

Table A.3c. Template/patient analysis - adult migration

Life History Type	ADULT MIGRATION						
	Hydrograph	Timing	Survival/ Blockages	Species Interaction	Ocean Distribution	Fisheries Interception Ocean/Estuaries/ Rivers	Life History Summary
	Template						
	Patient						
	Template						
	Patient						
	Template						
	Patient						
STOCK SUMMARY							

APPENDIX B

INSTITUTIONAL CONSTRAINTS ON SUPPLEMENTATION

B.l PURPOSE, SCOPE AND METHODS

The purpose of this Section is to describe the institutional constraints on restorative supplementation: the use of supplementation to restore a listed stock or to rehabilitate a depressed stock on the threshold of listing. "Supplementation" will be understood to represent "the use of ***artificial propagation in an attempt to maintain or increase natural production*** while maintaining the long term fitness of the target population and keeping the ecological and genetic impacts on non-target populations within specified biological limits" (RASP, 1993).

Constraints on conventional hatcheries will not be emphasized because their objectives and mode of operation either do not address, or are ultimately incompatible with, the fundamental goal of the ESA as applied to Pacific salmon: the reestablishment of self-sustaining, ecologically stable, natural populations with high genetic diversity. Conventional 'hatcheries strive · to maximize sustainable harvest and to minimize or eliminate "surplus [natural] spawners" which contribute neither to catch nor broodstock; they require continuous management; their populations are almost always subject to intentional or inadvertent selection; and the fish and fisheries they sustain are capable of a host of destabilizing impacts on the ecosystem.

There are, to be sure, many serious interactions between natural stocks and conventional hatcheries, including overharvest of natural fish in mixed-stocks fisheries, and ecological interactions (e.g., straying, displacement, competition and predation) that could cause serious declines in productivity or local extinctions of wild/natural populations. These issues are, however, being comprehensively addressed by the Integrated Hatchery Oversight Team (MOT) convened by the Power Council, and need not be addressed here.

It was originally intended that institutional constraints on restorative supplement&ion would be described for the following agencies: the National Marine Fisheries Service (NMFS), the Washington Department of Fisheries (WDF), the Oregon Department of Fish and Game (ODFW), the Idaho Department of Fish and Game (IDFG), the U.S. Fish and Wildlife Service (USFWS), the Washington Department of Wildlife (WDW) and the Columbia River Intertribal Fish Commission (CRITFC). With the exception of NMFS, source material for this effort was to be documents summarizing policies and guidelines for artificial propagation supplied by agency delegates to MOT. The source material for NMFS is Hard et al., (1992). Unfortunately, no source documents were received from WDW, USFWS and CRITFC (a detailed ***intertribal*** consensus on supplementation policy may not exist). Accordingly, these agencies will not be included in this report. All policies and assertions attributed to WDF, ODFW and IDFG are based on the IHOT summaries. Although NMFS's interpretation of the broad implications of the ESA for restorative supplementation was reviewed in a previous section, their detailed recommendations for implementation will not, except in highly condensed tabular form (see below). These specific recommendations, which amount to a manual on restorative supplementation, are also presented in Hard et al. (1992). The reader is strongly encouraged to review this document for the perspective casts on the mechanisms of supplementation.

A comprehensive genetic analysis of policies and guidelines for salmon and steelhead hatchery production in the Columbia Basin was prepared for the Power Council in January of 1991 (Kapuscinski, 1991). This document addressed relevant policies within the USFWS, WDW, WDF and IDFG, and might have been used in this report except for evidence that it has become somewhat dated over the past two years. The reader is, nevertheless, encouraged to read this document for the excellent overview it presents and its analysis of the semantic ambiguity that characterizes discussions of genetic issues between agencies, and for its analysis of the fundamental genetic difficulties inherent in artificial propagation of salmon and steelhead.

The institutional constraints for each agency reviewed will be examined from two general perspectives: constraints attributable to policies regarding wild, natural and hatchery fish, and constraints on detailed program implementation. Program implementation details will include broodstock source, impacts on donor population, number and kind of adults mated, fertilization protocol, rearing practices, release procedures, precautions against straying, monitoring and evaluation, and compliance monitoring and reporting, and program planning and development.

A highly condensed table (Table B-l) summarizing agency consideration of program implementation will be presented in the next section before the textual accounts. It is intended that this matrix be used as a quick check-list for determining the degree of consideration agencies accord each issue. With one exception (NMFS), the table, as well as the explanatory text, are based on policy summaries presented to IHOT. The recommendations made by NMFS were excerpted from Hard et al. (1992).

B.2 SUMMARY MATRIX OF INSTITUTIONAL CONSTRAINTS ON SUPPLEMENTATION PROGRAM

Table B-1. Degree and basic type of **institutional constraint imposed on** restorative **supplementation** by **required procedures** for **program development** and **implementation.**

LEGEND: - denotes negligible consideration of and constraint from the element indicated; ○ indicates tangential treatment and slight constraint; ■ indicates substantial treatment and substantial constraint.

SPECIFIC **ELEMENT**	**NMFS**	WDF	**ODFW**	**IDFG**
Program development	■ **Statutory requirements** for **elements** of recovery **program, Sect. 7 & 10 consultation, permitting requirements; listing & delisting criteria; requirement to change program when "appreciable hatch/wild differences** develop, or **adverse ecological impacts of hatch fish on wild occur.**	■ [illegible] **scheduled, distinct development program in place;** provisions for **internal/external review;** clear approval **process;** program **details** and log of changes in **modem-** accessible computer database; **little required** risk **analysis** except for selective breediug **programs.**	□ **Littlemention**[illegible] **discrete planning & development process; programs developed within Area, Basin &** species **Management Plans, consistent with Goals, Policies & Operating Principles; Oregon Fish & Wildlife** Commission approves **plans after public hearings.**	□ No **description** of **discrete development/planning program; program** developed **under Drainage Management Plans consistent with long-range** goals, policies **&** principles; Idaho **Fish** and Game **Commission has** approval authority; **no required risk analysis** mentioned.
Broodstock [illegible]	a **Exclusively**[illegible]**ESU; intra-ESU distinctions; extensive subsampling rules.**	0 [illegible]**restrictions**[illegible] production **hatcheries (transfer guidelines)** but **nothing** comparable for **supplementation.**	■ [illegible]**gen conservation** group or **wild** stock, 30% wild **"infusions/yr,** 25% cap on **broodstock take, wild-type phenotypes; <10% natural** spawners **when** conditions unmet except 1 generation for "special rehabilitation".	■ **From targeted natural** population or from adjacent, **environmentally** similar drainage.
Impacts on donor population	■ **Methods to maintain genetic variability** of **supplemented** population; conditions for **subsampling vs** total capture of **ESU** for **broodstock.**		■ **Broodstock rules also** protect donor **population;** must **define** tradeoffs **between minimal hatchery** and donor population **sizes; mandate** for corrective action **when** program **threatens to reduce** donor population to 300 individuals.	■ **Extensive** effort to **prevent broodstock** mining, provide for effective **size** of donor populations in broods&k **collections at weirs.**

Table B-1. Degree and basic type of institutional constraint imposed on restorative supplementation by required procedures for program development and implementation.

LEGEND: - denotes negligible consideration of and constraint from the element indicated; O indicates tangential treatment and slight constraint; ■ indicates substantial treatment and substantial constraint.

SPECIFIC ELEMENT	NMFS	WDF	ODFW	IDFG
Number and type of adults mated	■ Minimum size re. drift; methods to maintain N_e by reducing family size variability re. mating protocols.	■ Male/female spawning ratios prescribed for 4 "Cases" re. return size and timing (Case 1 - supplementation); rules for mating across ages, sizes, return times; minimum no. spawned by sex; rules for spawning jacks; conditions on selective breeding.	■ Subsample representatively through an ages, run-times, spawning times, sizes; collect >100 males/females; individual matings; plans reviewed by geneticist; selective breeding allowed.	0 Type, but not minimum number, discussed; 1:1 male/female mating, non-selective broodstock sampling re. all characteristics except disease.
Fertilization protocol	■ Gamete mixing to minimize family size variation (one female with overlapping pairs of males).	■ Gamete mixing to minimize family size variation (mixture of milt from x males mixed with eggs from x females).	■ Mate 1 male with 1 female and don't pod sperm.	0 1:1, male/female; detailed handling of gametes (e.g., sperm pooling) not discussed.
Rearing practices	■ Trade-offs between numerical increase, genetic/ecological divergence hatchery from wild; recommendation & description of naturalistic rearing procedures.	0 Unspecific - "ensure equal rearing conditions for all groups".	0 Rear all spawning group under same conditions; rear groups spawned at different times separately until same size and then mix to maximize survival of each group.	■ Charged to produce hatchery fish behaviorally/ecologically compatible with wild/natural; developing some elements of naturalistic rearing.
Release procedures	■ mimic spatiotemporal movements with hatchery releases; mimic distribution of measurable wild attributes; provide prolonged acclimation (consider release of pre-smolts).	□ Ensure equal proportions all spawning groups released; keep sex ratios balanced by selecting smolts for release after all show signs; timing determined by "biological data".	■ Size, season & manner of release defined by management goals and survival; total number hatchery fish released subject to cuts when hatchery spawners exceed limits in wild streams; receiving stream receives progeny from all group6 spawned; release above fisheries iu underseeded areas.	□ Time & place of release manipulated to reduce straying & residualism (few details); release size determined primarily by survival data (wild size distribution uot mimicked).

Table B-1. Degree and basic type of institutional constraint imposed on restorative supplementation by required procedures for program development and implementation.

LEGEND: - denotes negligible consideration of and constraint from the element indicated; O indicates tangential treatment and slight constraint; ■ indicates substantial treatment and substantial constraint.

SPECIFIC ELEMENT	NMFS	WDF	ODFW	IDFG
Precautions against straying	■ **Mark all hatchery fish; provide prolonged acclimation or release pre-smolts.**		■ **Size, season and manner of release manipulated to maximize homing fidelity; hatchery release cut-backs based on hatchery straying; statutory ban on more than 50% hatchery fish on wild spawning grounds regardless of parentage (few enforcement details** provided).	▯ **All hatchery fish marked, can be excluded** at **weirs** (few **details);** no **releases of hatchery fish in wild streams; time/place manipulation to reduce straying; ban** on more than 50% **hatchery fish on spawning ground in** some drainages (few **enforcement** details).
Monitoring and **evaluation**	■ Monitor **genetic variability, phenotypes, life** history traits of **hatchery and wild fish** for **development** of **"appreciable differences;** monitor **production of progeny from naturally** spawning **fish;** monitor **egg/smolt, smolt/adult survival** of hatchery **fish, by family if possible.**	0 **"Performance" (survival?)** of **hatchery/wild** hybrids; **classify** stocks **genetically,** monitor genetic changes; monitor genetic **distinctiveness** of **multiple stocks in same hatchery.**	0 **Smolt/adult survival;** hatchery/wild **composition among wild stream breeders; homing fidelity; residuals; rebuilding** of' **targeted underseeded** areas.	0 **Much** more M&E **implied** than **described; no explicit genetic monitoring discussed;** M **"unevaluated"** supplementation **permitted; intent to** monitor natural production, survival, straying, **natural** spawner composition (few details).
Compliance monitoring **and reporting**	■ **NMFS oversight** of **recovery program; regulations of directed** and incidental take.	■ **Extensive use** of **computerized system** for **reporting program operations, changes; degree** of **compliance** monitoring per se **unclear.**	■ **Biennial Wild Fish Management Report: numbers, habitat conditions, harvest, hatchery releases, list of wild populations not subject to rules; list of populations severely reduced or lost and consequences** to **genetic resources.**	

B.2.1 Idaho Fish And Game

B.2.1.1 General Policies

Idaho's broad policies include long range anadromous fish program goals and associated policies as well as five-year management strategies for wild, natural and hatchery populations. (See Definitions section for IDFG's definitions of wild, natural and hatchery fish).

The long-range anadromous fish program goal is as follows:

"Maintain genetic diversity and integrity of both naturally-produced populations and artificially-produced fish used for natural production enhancement. Maintain natural production and productivity of wild and natural fish populations, ***where natural production potential is significant*** [emphasis added]."

The phrase, "where natural production potential is significant" seems to imply that wild/natural populations facing apparently insuperable obstacles may be officially written off and left to their fate. If this interpretation is correct, it would represent a conflict with the ESA.

The long-range anadromous goal provides additional detail is provided regarding production of hatchery fish and long-term genetic concerns. One of the goals of the department is to maximize harvest opportunities for hatchery fish contingent upon maintenance of long-term hatchery production and productivity and minimal [adverse] impacts to natural populations. The long-range goal recognizes potential adverse genetic impacts to both wild/natural and hatchery populations is a major concern. It identifies the current excessive proportion of hatchery fish in adult returns as a threat to the maintenance of wild populations and possible genetic management strategies.

Policies 1, 2, 6, 7 and 8 from the "IDFG Policy Plan, 1990-2005" were described [the reason for the omission of Policies 3-5 was not discussed in the IHOT document]. The relevant items for this report are as follows:

♦ Policy 1 states that "Idaho waters will be managed to provide optimum sport fishery benefits". Three significant principles of this policy are that established hatchery operations will be managed primarily to provide harvest opportunity, and secondarily to provide fish for supplementation programs; that hatchery fish intended for harvest and sustaining hatchery operations ("production fish") will be marked; and that future development of Idaho Snake River fall chinook and sockeye artificial production and harvest will be compatible with genetic and natural production guidelines.

♦ Policy 2 states, "Wild native populations of resident and anadromous fish species receive priority consideration in management decisions." A significant principle of this policy is that sites and strategies for the release of hatchery smolts will be chosen to minimize the risk of hatchery fish straying and spawning with wild fish.

- Policy 6 states, "hatchery fish will be stocked to establish or reestablish depleted fish populations, and to provide angling opportunity for the general public". Pertinent principles under this policy include: support for supplementing specific populations using a conservation hatchery concept and evaluating results through adaptive management;. commitment to managing hatchery production "for rebuilding natural production" so that hatchery fish remain genetically and behaviorally compatible with natural populations ***to the greatest extent possible*** [emphasis added]; and differentiating between "rebuilding" and "harvest augmentation" supplementation. The goal of rebuilding supplementation is defined as the use of natural rearing habitat for the production of smolts and adults for rebuilding natural populations to harvestable levels, whereas the goal of supplementation for harvest augmentation is use of natural rearing habitat to produce smolts and returning adults for harvest. Significantly, returning adults are not harvested in rebuilding supplementation, while no emphasis is placed on natural spawning escapement in supplementation (outplanting) for harvest augmentation.

- Policy 7 states that "the Department will strive to maintain the genetic integrity of wild native stocks of resident fish and naturally managed anadromous fish when using hatchery supplementation". Three principles associated with this Policy are germane. First, wild, native stocks [of anadromous fish] will not be supplemented. Second, hatchery fish used to supplement natural populations will be representatives of stock "endemic" to the drainage supplemented or, as a second priority, of a stock from adjacent and environmentally similar drainage. Finally, first priority in the management of weirs for the collection of hatchery broodstock will be given to providing adequate natural escapement to sustain the "genetic fitness" of natural donor populations. [Note that this policy has apparently been updated since Kapuscinski's 1991 review, which reports a general, state-wide broodstock collection cap of 2/3. The MOT document lists many weir management protocols, including general, unquantified injunctions to provide adequate natural escapement, 2/3 caps, 1/3 caps and management such that natural escapement is 50/50 hatchery/natural.]

- Policy 8 states that "non-native species of fish will be introduced only in waters where they are not expected to adversely impact stocks of wild native fish". A germane principle of this policy is that reintroduction of non-native coho or sockeye will be undertaken only if feasibility studies indicate that "significant potential impacts" on existing species and stocks of fish will not occur.

Idaho's five year management strategies attempt to mesh the long-term goals and policies described above with "the biological reality of low run sizes in the near term". Idaho has developed separate management strategies for wild, natural and hatchery populations. The general thrust of management over the next five years will be to "maximize wild and natural production opportunity while producing fishery opportunity with hatchery production." Special emphasis is placed on maintaining natural production and genetic resources, maintaining a secure wild fish management program and minimizing interactions between natural and hatchery fish.

B.2.1.2 Wild Fish Management Strategy

For wild fish strategy emphasizes preserving genetic resources and fitness. Importantly, wild anadromous stocks will not be supplemented, and the release strategies for hatchery programs [presumably both conventional and supplementation-type] will be designed to minimize impacts on wild populations attributable to residualism of juveniles and straying of adults. Use of some wild fish for the evaluation of experimental captive broodstock programs may be considered providing donor populations can safely provide the required broodstock.

B.2.1.3 Hatchery fish management strategy

Idaho's hatchery fish management strategies focus on increasing smolt-to-adult survival rates and maintaining the genetic resources of existing hatchery stocks. With two exceptions, they have little direct relevance to restorative supplementation (although they are very germane to the IHOT activities described previously). These exceptions are:

- An effort will be made to develop a range of marking techniques that can be used to visually identify hatchery fish in selective fisheries, and in the development of refined procedures for operating weirs to collect broodstock while providing for adequate escapement of naturally reared fish.

- Some hatcheries will be managed specifically to provide the best "product" for experimental evaluations of [rebuilding] supplementation. Natural brood will be taken from existing populations with adequate escapement, and their progeny will be handled as naturally as possible to minimize the influence of the artificial rearing environment. These experimental programs will be evaluated in terms of the post-release survival and, especially, reproductive success of the fish produced.

B.2.1.4 Natural Fish Management Strategy

Although the fact is scattered throughout the text, the IHOT document indicates that many of Idaho's existing marginal natural populations probably originated from non-native fish stocked after indigenous populations were exterminated or drastically depressed by a variety of anthropogenic factors. This fact, in combination with low smolt-to-adult survival rates attributed to the hydroelectric system and pre-terminal harvests, makes it difficult to evaluate supplementation: should the lack of increased natural production in a supplemented population be attributed to bad technique or bankruptcy of the entire approach? Or should it instead be attributed to a natural population that is poorly adapted to its environment -- in effect, to a poor choice of donor stock?

The evaluation quandary, the expectation that existing smolt-to-adult survival rates may preclude meaningful rebuilding, and evidence that past indiscriminant outplantings of surplus hatchery production may have negatively impacted natural productivity has compelled IDFG to take a conservative approach to supplementation in the near term. The majority of existing production facilities will be devoted to harvest augmentation exclusively. The smaller number exclusively devoted to supplementation will do so only in the context of regionally coordinated and Department-approved studies, and only for those populations that can bear the removal of adults for broodstock.

The IHOT document implies that supplementation efforts will increase when passage conditions improve enough to allow definitive assessment, perhaps allowing the identification of “maladapted” populations. At this point, “suitable” populations will be rebuilt by supplementation, while some of the rest receive outplants for harvest augmentation.

B.2.1.5 Program Development and Implementation

Very little information relating to a discrete process of program development was included in the MOT documents. The wild, natural and hatchery fish management strategies amply describe the conditions placed on supplementation, but the process of translating these conditions into a concrete program were not described.

All Idaho programs are developed under specific five-year Drainage Management Plans, which are consistent with wild, natural and hatchery management strategies and the long-range anadromous fish program goals, policies and principles. The Idaho Fish and Game Commission has the statutory authority to manage fish and wildlife (Title 36, Idaho Code), and is directed to “preserve, protect and perpetuate such wildlife and provide for the citizens of the state and as by law permitted to others, continued supplies of such wildlife for hunting, trapping and fishing”. Accordingly, the Fish and Wildlife Commission has the ultimate authority to approve any Drainage Management Plan which might provide for restorative supplementation.

As mentioned in the previous section, Idaho’s fisheries are managed by individual Drainage Management Plans which are consistent with wild, natural and hatchery fish management strategies and long-term goals, policies and principles. There are 16 separate Drainage Management Plans (Snake, Lower Clearwater, South Fork Clearwater, Middle Fork Clearwater, Lochsa, Selway, Lower Salmon, Little Salmon, Salmon River Canyon, South Fork Salmon, Middle Fork Salmon, Lemhi, Pahsimeroi, East Fork Salmon, Yankee Fork Salmon and Upper Salmon). As production in each of these drainages consists of a unique mixture of species and wild, natural and hatchery stocks in varying degrees of abundance, the details of supplementation plans that are or might be contemplated in the state are too complex to be concisely summarized.

It is, however, possible to summarize the elements of restorative supplementation that, in one form or another, all or most Drainage Management Plans consistently address or fail to address.

Broodstock source is always addressed, and consists of fish from the targeted population or a population from (perhaps *originally* from) adjacent and environmentally similar drainages. Plans are under way to develop a steelhead broodstock for supplementing the upper Salmon drainage and the Clearwater drainage from several highly productive tributaries in the Salmon River Canyon and a tributary of the Lochsa River, respectively.

Impacts on donor stock of a supplementation program are unfailingly addressed. These protective measures are intended primarily to prevent "mining" of the natural population by an possibly ineffective supplementation program, but also help to protect effective size and perhaps to guard against introgression of "domesticated" hatchery genotypes. Protection against adverse impacts to the donor stock involves the use of broodstock collection weirs such that natural escapement needs are satisfied prior to broodstock collection. All of these efforts involve the use and refinement of visual marks to allow hatchery fish intended for harvest and rebuilding to be identified. The general plan for a number of supplementation weirs is to release only marked supplementation juveniles while collecting a fixed percent (often 1/3 or 2/3) of all returning adults for broodstock. When all returning hatchery adults are marked, all unmarked natural fish will be passed over the weir, and only hatchery fish will be used for broodstock. When natural escapement goals can be met entirely with natural fish, they will gradually be incorporated into the supplementation program. When stated, the maximum hatchery/wild ratio for adults permitted on the spawning grounds is 50%.

The type, although not the minimum number, of adults mated in supplementation programs is reasonably well covered. The standard male/female mating ratio is 1: 1 and non-selective. broodstock subsampling is used for all characteristics of the donor run except incidence of transmissible diseases.

Rearing and release practices are addressed in some detail. The stated objective for hatchery-reared juveniles is, to the greatest extent possible, to produce fish that are behaviorally and ecologically compatible with wild fish. Areas of emphasis include some elements of naturalistic rearing (provision of "shared structure" and variable velocity in rearing vessels) intended to reduce domestication and adverse behavioral impacts. Supplementation hatcheries are also charged with the development of pre-smolts that can survive well through the winter. Release time, place and size will be experimentally manipulated to reduce straying and hatchery/wild interactions attributable to residualism. Possible impacts on wild populations will be precluded by prohibiting the release of any supplementation fish in the natal stream of a wild population. Except for the sorting of marked hatchery fish possible at broodstock- weirs, these release procedures also represent the major precautions against straying. An element of the release program that is perhaps somewhat at odds with the otherwise "naturalistic" tenor of the preceding release strategies is the practice of setting the size of released smolts on the basis of observed smolt-to-adult survival rates. This practice could preclude the release of fish with a size distribution characteristic of natural fish, and therefore could represent a form of directed selection on the supplemented population.

Considerably more monitoring and evaluation is implied than described. It is, for instance, stated that no ad hoc, unevaluated supplementation projects will be permitted, and the impression is given that evaluation will, among other things, estimate real impacts of supplementation on natural production. However, the techniques that will be employed to evaluate supplementation were not described. Also implied but not described is the evaluation of release procedures intended to reduce straying and the monitoring of the hatchery/wild composition of natural spawners. The experimental assessment of rearing and release techniques to reduce residualism and the possibility of adverse inter- and intra-specific impacts on wild/natural fish also implies some evaluation, at least of rates. of residualism. Similarly, experimental rearing techniques intended to intended to improve overwinter survival of hatchery-reared pre-smolts imply a study of survival by life stage. However, no indication or implication of the intention to conduct explicit genetic monitoring was evident in the IHOT documents.

The handling of gametes in hatchery mating and compliance monitoring were not discussed.

B.2.2 Oregon Department Of Fish And Wildlife

B.2.2.1 General Policies

The activities of ODFW are organized both hierarchically, by levels of generality, and by the object of management -- geographic area, basin or other "waterbody", or species.

ODFW breaks its activities down into hierarchical levels termed goals, policies, -operating principles, objectives and guidelines. At the top of the hierarchy are goals, which are broad statements of official intent; at the bottom are guidelines, which are detailed and usually optional "advice" for accomplishing specific activities. Goals provide the framework for policies or "rules", which define mandatory direction and constraints for all departmental programs. Operating principles provide more detailed, and still mandatory, direction under specific policies or rules. This series of intentions, policies and operating principles is finally translated into activity in the form of objectives, which are specific results to be achieved by a predetermined date. Reflecting their mandatory nature, goals, polices and rules and operating principles have the legal status of an Oregon Administrative Rule (OAR).

Parallel to Goals, Policies/Rules and Operating Principles are Management Plans for "areas" (a stream, a lake, a group of streams or lakes or a portion of the ocean managed for a common stock of fish), subbasins and species. Management Plans are adopted by the Oregon Fish and Wildlife Commission in public hearings and are consistent with (or strive to attain consistency with) the general regulations.

The preceding dissertation on the logical organization of ODFW's activities is not wholly the digression it seems. ODFW's intricate structure of regulations makes it difficult to track a single issue, like restorative supplementation, over all relevant areas. Moreover, the layered and clustered regulations make it rather cumbersome to document specific attributions. Some comprehension of the structure of ODFW's regulatory structure is therefore essential at the outset if the significance of individual regulations is to be understood. It should, however, be noted that giving the force of law to fisheries management policy is an excellent way to guarantee policies are actually implemented and is well worth the paperwork.

The relevant issues for the ODFW section of this report were found in one species Management Plan, the Steelhead Management Plan; and in a number of Administrative Rules. The Administrative Rules cited include: the General Fish Management Goals (OAR 63 5-07-5 10), the

General Fish Management Policy (OAR 635-07-5 15), the Operating Principles for Natural Production Management (OAR 635-07-523), the General Policies of Wild Fish Management (OAR 63 5-07-526), the Operating Principles for Wild Fish Management (OAR 63 5-07-527), the Implementation of Wild Fish Management Rules,..,[NOTE: The document ODFW provided IHOT contained only one of the three Administrative Rules dealing with Natural Production Management. The treatment of this issue may thus be incomplete.]

Several of ODFW's broadest goals are clearly compatible with the ESA's emphasis on preservation of ecosystem integrity and genetic resources. The General Goal of Fish Management identifies the overriding goal as "the prevention of serious depletion of any indigenous fish species through the protection of native ecological communities, the conservation of genetic resources and the control of consumptive uses such that fish production is sustainable over the long term". Under the Fish Management Policy, the first of the six "favorable continuing benefits" for which all Oregon fisheries are to be managed is "protection of genetic resources". The importance placed on preserving the ecological integrity of natural population is evident in one of the Operating Principles for Natural Production Management, which states that Department will oppose any fish introduction that allows "competition, predation or disease to prevent meeting natural production objectives and management plans".

The Fish Management Policy also directs ODFW, in its attempt to rehabilitate natural production, to "consider all viable alternatives, including habitat protection and improvement, artificial propagation, and harvest management." An apparent indication of the official assessment of the appropriate function of artificial propagation is evident in the injunction under the General Goals to manage hatchery fish "primarily for the benefit of consumptive users". This conservative impressions is, however, immediately tempered by an element of the natural production operating principles which calls for the "full use" of the potential of existing hatchery programs to "enhance natural production."

The Fish Management Policy also includes an element of harvest management that might conflict to some degree with the "indirect take" provisions of the ESA. Specifically, the Fish Management Policy states that an incidental harvest of a depressed stock in a fishery targeting a healthy stock might be allowed, although compensatory "rehabilitation and/or supplementation" of the depressed stock might be required.

By far the greatest number of relevant regulations are found in three Administrative Rules:. the General Policies of Wild Fish Management, the Operating Principles for Wild Fish Management and the Implementation of Wild Fish Management. The purpose of the wild fish management rules is specifically to conserve the genetic resources of wild fish in Oregon. Wild fish management rules apply to all wild populations of salmonids, green and white sturgeon and all species designated sensitive under OAR 635-100-040, ***and all threatened or endangered species.*** Thus, implementation of restorative supplementation in Oregon is directly impacted by the Wild Fish Rules.

The most pertinent portion of Oregon's wild fish policy is Section c. of the Operating Principles. This section mandates that potential threats to the genetic resources of wild fish attributable to interbreeding with hatchery fish be reduced by limiting both the number and the genetic characteristics of hatchery fish in the naturally spawning population. [Recall that ODPW defines a hatchery fish as a fish incubated or reared under artificial conditions for at least a portion of its life, regardless of parental ancestry.] This rule applies to all hatchery fish, "whether released on site [e.g., from a supplementation program] or from strays from other release sites". Section c. then lists the options consistent with the policy.

The available options are either to release no hatchery fish or, as authorized in an approved Basin Management Plan (OAR 635-07-529), to release hatchery fish that are genetically similar to the wild population under such conditions that hatchery fish represent no more than 50% of the natural breeding population. The genetic conditions placed on "acceptable" hatchery fish are that they originate either from the same "gene conservation group"' or the same wild population. Moreover, once such a program begins, at least 30% of the hatchery broodstock in every generation must consist of wild fish, and no more than 25% of the wild escapement may be taken as broodstock in any year. Finally, wild-type phenotypes must be maintained, precluding intentional selection and appreciable inadvertent selection in the hatchery.

The Operating Principles also require a monitoring program to ensure the conditions described above are met, and stipulate remedial measures which must be taken if they are not. Annual monitoring of conditions are required, and an "evaluation" is required every ten years [the difference between "monitoring" and "evaluation" is not explained]. Section d. of the Operating Principles requires that the proportion of hatchery spawners allowed in the wild breeding population be reduced in inverse proportion to the lack of conformance to the conditions stated above. Section d. also makes special provisions for the case in which the hatchery fish do not originate from the same gene conservation group or wild population, and are not the progeny of broodstock which includes at least 30% wild fish. Under this scenario, no more than 10% of the spawners in the wild population can be of hatchery origin. This stricture defines the limits of acceptable straying from harvest augmentation programs or supplementation programs targeting "other" wild populations, and is not directly applicable to restorative supplementation.

It should be noted that the Operating Principles *do* allow for one exception to the general rule that any supplementation project targeting a wild population must use local wild broodstock. Provision is made for the "special rehabilitation" (Section e.) of wild populations by supplementing with non-local hatchery fish if rehabilitation would be impossible otherwise, and if the duration of the program is one life-cycle or less and the rationale, standards and guidelines

[4] "'Gene conservation group' means a genetically distinct cluster of one or more populations within a taxonomic species that resulted because gene flow between the cluster and other populations of the same species has been zero or very low over sufficient geological time" (OAR 635-07-501).

of the program are documented in written form. This provision could easily conflict with the ESA requirement that broodstock for restorative supplementation come from within the ESU.

The final pertinent portion of the Operating Principles (Section f.) concerns adverse competitive, predatory or disease impacts on wild fish attributable to "the release or transplant of fish of the same or different species". ODFW is obligated to oppose any such releases that threaten to increase mortality within wild populations by any of these ecological mechanisms, and must take appropriate corrective action whenever there is reason to believe such impacts could reduce the abundance of a wild population to 300 individuals or less.

B.2.2.2 Program Development and Implementation

Very little material relating specifically to the process of developing hatchery programs was provided in the IHOT documents. Some indication of the overall development and authorization procedure was described, but no mention was made of required pre-implementation risk analyses or the provisions for monitoring and evaluation that must be made to move a plan from the planning to the implementation phase.

It is clear that Oregon waters are regulated by Area, Basin and Species Management Plans which apply general Goals, Polices and Operating Principles to a specific aquatic system or species. The Oregon Fish and Wildlife Commission has the authority to approve these plans after public hearings in which specific objectives and operating plans are discussed. Restorative supplementation must be an element of an approved Basin Management Plan to be implemented.

ODFW's wild fish management rules constrain restorative supplementation rather tightly with regard to broodstock source, donor impacts, release procedures and precautions against straying. The detailed broodstock requirements applicable to supplementing a wild population have already been described. The same is true for permissible impacts on the donor population with one exception: Basin Management Plans must explicitly describe how the dilemma of collecting enough broodstock to guard against loss of within-population genetic variability will be balanced against the requirement that the genetic variability of the fish in the natural spawning escapement be preserved.

Oregon guidelines for adults mated are also rather specific: if possible, at least 100 males and females should be subsampled across all phenotypic strata (e.g., age, size spawning timing, run timing). Fertilization protocols call for individual matings without the use of pooled sperm. In addition, Oregon requires the input of a geneticist in the design of mating strategies for supplementation.

The mixture of guidelines and operating principles focussing on release is extensive. Most of these measures are intended to improve survival, reduce adverse hatchery/wild interactions and, especially, minimize straying. Precautions against straying are "enforced" by the annual determination of whether all releases of hatchery-reared fish should be reduced to lessen straying, particularly straying into wild fish streams. When straying is excessive, ODFW orders release cut-backs, in descending order of priority, from the following. types of hatcheries: Departmental programs, Public hatcheries and STEP (Salmon and Trout Enhancement Program) facilities; other publicly and federally funded hatcheries, and programs under the state restoration and enhancement program; and private hatcheries. Size of fish released and release timing and location are manipulated to achieve program goals (e.g., high fidelity homing to underseeded habitat, minimal adverse impacts from hatchery residuals) and, especially, to improve survival. To maximize survival, ODWF sets minimum smolt **size** targets based on return rate data; the size distribution of local wild **fish** is not necessarily mimicked. The targeted, stream must receive releases of progeny from all spawning periods, and measures are taken to **ensure** fish from all spawning groups have a comparable chance of survival. Juveniles from different spawning periods are initially reared separately to preclude competitive impacts on younger fish, and growth programming is adjusted to allow all fish to reach equivalent size before being mixed prior to release. Guidelines for the timing of smolt releases are also intended to maximize survival, and are based on: outmigration periods of wild smolts; probability of minimizing residualism; "windows of opportunity" for avoiding disease, predation and temperature problems; and periods of high flow. Guidelines for the time and size of pre-smolt releases have not been developed.

Monitoring and evaluation and, especially, rearing procedures were not extensively discussed in the **IHOT** document. Rearing guidelines consisted of general guidelines that fish be reared in a clean environment, at proper densities, and that stress in cultural practices be minimized. Hatchery managers are advised to provide uniform rearing conditions for **all** spawning groups. As was the case with IDFG, considerably more monitoring and evaluation was implied than described. Topics of evaluation that were mentioned or implied but not described in detail include: survival, spawner composition in the wild, homing fidelity of supplementation fish to release areas, and residualism. Explicit genetic monitoring was not described.

ODFW does have a very well developed compliance monitoring and reporting system in the Biennial Wild Fish Management Report. This document: lists latest figures for the **abundance** of wild populations, changes in their habitat, harvest activities, and hatchery introductions; identifies individual wild fish populations not being managed in conformity to wild fish policy and the reasons why this is occurring; and lists population segments reduced or lost, and the impact of these developments on the long term fitness of Oregon's wild stocks.

B.2.3 Washington Department Of Fisheries

B.2.3.1 General Policies

The material WDF presented to **IHOT** includes no programmatic policies that would specifically **guide or** constrain the management of wild/natural populations. Certainly, nothing comparable to Oregon's wild **fish** policy, or Idaho's wild, natural and hatchery fish policies, was described.

The bulk of the WDF material is titled, "Spawning Guidelines for Washington Department of Fisheries Hatcheries", and represents, essentially, a primer on population genetics written from the perspective of an animal breeder. These Guidelines include extensive, quantitative descriptions of the mechanisms of artificial and natural selection, heritability, inbreeding, qualitative and quantitative traits, and so on, and give considerable instruction on maintaining genetic variability and avoiding inbreeding in hatchery populations. They provide, however, very little direction in the application of these principles to the management of wild/natural populations. There are, to be sure, frequent references to the adaptive significance of genetic differences between stocks, and general admonitions against compromising natural genetic resources by avoiding Type 3 impacts (introgression of dissimilar hatchery genotypes and loss of between-population variability in the natural stock). But no coherent strategy for avoiding Type-3 impacts, or for avoiding other genetic or ecological impacts, is described, and no systematic principles for supplementation are presented.

A final comment on general policy concerns selective breeding. Of all the agencies reviewed, WDF appears to have the most favorable opinion of this practice. The following excerpt from the Guidelines perhaps encapsulates the attitude:

> "With proper thought and planning a program could be initiated to improve traits of importance to the fishery and to management (e.g., return timing, adult size, survival to adulthood, growth rate, etc.). This type of approach will be mandatory for commercial ocean ranching if it is to advance. Perhaps in our rapidly changing world we need to change our approach of preservation of naturally occurring genetic components to some emphasis on selecting characteristics that are advantageous to salmon."

B.23.2 **Program Development and Implementation**

In developing new projects, WDF follows a well-defined planning sequence with clearly defined roles. The Assistant Chief, Assessment and Development of WDF's Salmon Culture division has the responsibility for developing new programs and presumably, after review, approving them. The developmental process follows an annual schedule, and entails systematicinternal (Harvest Management Chief, Regional Harvest Management Assistant Chiefs, any other interested parties within WDF) and external (WDW, USFWS, Tribes and Co-ops, other interested parties) review. Both review processes are facilitated by an interactive computer system which describes details, tracks changes and logs the history of all programs. The interactive computer system is the preferred mode of communication both internally and externally. Program changes require internal review similar to program development and are also "posted" to the computer system. However, no general principles constraining the nature and scope of program changes were described. Presumably, the interactive computer database can be used to monitor program compliance with policy and guidelines, although no explicit provisions for monitoring compliance, outside the established internal review process, were described.

Virtually no mention of required risk analysis or provisions for monitoring and evaluation were described for the planning and development process. Only one example of risk analysis, applying to development of selective breeding programs (cost/benefit with respect to effort and risk of inadvertent change in non-selected traits), was found in the IHOT documents. No mention of provisions for M&E during the development phase was found.

WDF provided detailed guidelines for determining the number and type of fish to mate and specific instruction on fertilization protocol. Considerably less guidance was provided for selecting donor stocks, release procedures, and M&E. Treatment of impacts on donor populations, rearing practices, precautions against straying, and compliance monitoring was negligible or non-existent.

Substantive direction for the number and kind of fish to mate was provided. Hatchery operations were divided into, four "Cases" determined by expected escapement size and the need to preserve specific temporal segments of the run. Spawning guidelines were provided for each case. These guidelines address male/female spawning ratios, fertilization protocols, broodstock subsampling through the run, and the use of jacks.

The four Cases are as follows:

Case 1: Adult return egg take potential below desired escapement goal. Includes egg banks.

Case 2: Adult return egg take potential above desired escapement goal, but every female will be spawned: surplus eggs will be shipped out for use at another facility.

Case 3: The egg take potential is well above desired escapement goal, and there is no need to spawn every female.

Case 4: Where the station goal is to preserve specific run-timing segments or where cutoff dates are used to separate any of the following: spring, summer, fall chinook; early, normal, late chum; summer, fall, normal, north or south coho.

The Case which most corresponds to restorative supplementation is the first; the other Cases are not consistent with a supplementation scenario, and there is no need to describe specific spawning guidelines associated with them.

Case-l stocks are described as. "small populations which are not geared toward emphasizing production, but rather maintaining the stock at an appropriate size to preserve [genetic] diversity for future use". The recommendation for such stocks is that the male/female spawning ratio be 1: 1. The guidelines urge that every effort be made to maximize the contribution of each adult spawned by exercising care in fertilization techniques and ensuring each spawning group is reared under equivalent conditions.

The remaining guidelines are the same for all Cases. To minimize variable male contribution to progeny and increase effective size in the hatchery, milt from the proper number of males should be collected in a container and mixed with eggs from the proper number of females in a separate container. A representative portion of each run (size, age, timing) should be taken as broodstock.

Whenever possible; at least 100 females and 100 males should be included in the spawning population, although temporary "bottlenecks" of as few as 25 individuals of either sex may be permissible. Jacks are to be introduced at a rate of no more than 2% in order to preserve the element of genetic diversity they embody while offsetting the agefrequency distortions (accelerated maturation) associated with size selective fisheries and hatcheries practices.

Although and detailed guidance on broodstock source is given for existing production hatcheries in the form of stock transfer guidelines, no consideration is given to broodstock appropriate for supplementation. Similarly, it is stated that the interbreeding of hatchery and neighboring wild/natural stocks is to be avoided, but specific precautions to avoid hatchery straying are not provided. Suggested monitoring and evaluation is limited to genetic classification and the monitoring of genetic changes [presumably for hatchery stocks], and the monitoring of "performance" of hatchery stocks incorporating genetic material from neighboring wild stock. Donor stock impacts and compliance monitoring are not mentioned

Very little discussion of monitoring and evaluation was included in the IHOT documents. The few items that were discussed briefly included: "performance" of hatchery/wild hybrids; genetic classification of (hatchery?) stocks; need to monitor genetic changes in (hatchery?) stocks and to ensure no gene flow occurs between distinct stocks propagated in the same hatchery.